

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



ANALYSIS OF TRACE METALS IN BOTTOM SEDIMENTS IN SUPPORT OF
DEEPWATER BIOLOGICAL PROCESSES STUDIES ON
THE U.S. MID-ATLANTIC CONTINENTAL SLOPE AND RISE

By

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January 24, 1986

Second Interim Report submitted to the
U.S. Minerals Management Service under
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This report has been reviewed by the Minerals Management Service (MMS) and approved for publication. Approval does not signify the contents necessarily reflect the views and policies of the MMS, nor does mention of trade names or commercial products constitute endorsement or recommendation for use by MMS or the U.S. Geological Survey.

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ABSTRACT

This study is part of a multidisciplinary program conducted on the continental slope and rise off the North, Mid-, and South Atlantic states to characterize the biology, chemistry, and geology of the sea floor in anticipation of exploratory drilling for petroleum resources. The specific objectives are to measure and evaluate the extent of environmental changes which may relate to drilling activities in the area during the period of study. In this report we use trace-metal concentrations to assess both the depositional pattern and fate of discharged drilling mud.

Sediment samples collected during the first four cruises to the continental slope and rise off the Mid-Atlantic states have been analyzed for 12 metals (Al, Ba, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, V, and Zn). Because of its high concentration in drilling mud, Ba is most commonly measured to trace drilling mud in the marine environment. In the Mid-Atlantic area, our measurements show only small changes in Ba concentrations in sediments. In one core collected during Cruise 3 at Station 1, adjacent to the drilling site

in Block 372, the Ba concentration in the surface sediment was 13 percent higher than measured deeper in the core. Neither samples from other replicate box cores from Cruise 3, Station 1 nor replicate sub cores from the same box core, show the same increase, indicating a patchy distribution of drilling-related Ba. There is no obvious trend of increasing Ba concentration in blended surface sediment from Station 1, Cruises 1-4. The average concentrations of Ba at Station 1 are in line with stations away from drilling rigs having similar grain size.

The average Ba to Al ratio at Station 1 in bulk (undifferentiated) sediment was 6 percent higher in postdrilling than predrilling samples. This difference is significant at the 95 percent level of confidence.

The enrichment in Ba and Ba to Al ratio measured at Station 1 is probably not harmful to benthic organisms. However, there is little data in the literature which evaluates the response of organisms at different life stages to long term, low level contamination of sediments.

At Stations 13 and 14, near the site of drilling in Block 93, there is no significant change in the average Ba concentration during the first four cruises.

The strongest signal from drilling mud was measured in sediments collected in sediment traps positioned in the upper 850 m of the water column at a mooring located 1.8 km south-southwest of the drilling rig in Block 372. Preliminary examination, using a scanning electron microscope equipped with an X-ray detector, revealed discrete particles of barite in the sample.

For samples collected from the study area during Cruise 1, the distribution of metals in surface sediments appears to vary with the changes in the concentrations of fine sediment and organic carbon. The concentrations

of the metals analyzed in these sediments are the same or lower than they are in average shales from around the world, and are characteristic of uncontaminated sediments. The highest concentration of Ba increased in sediments at Station 1 (509 ppm) is considerably less than the concentration in average shales (580 ppm). Pb concentrations are consistently higher in the upper 5-10 cm of sediment than in deeper sections of sediment cores, but the average values in surface sediments do not exceed those measured in average shales. Pb enrichment in surface sediments has been observed at other locations off the U.S. East Coast and is thought to be related to the onshore burning of gasoline containing Pb additives.

INTRODUCTION

This study was designed to establish the concentrations of trace metals in sediments prior to petroleum exploration drilling on the continental slope and rise off the U.S. Middle Atlantic States, and to quantify changes in trace-metal concentrations that are related to exploration activities. Some of the specific questions addressed during this three-year sampling and analysis program are: (1) Where do discharged drilling muds accumulate on the continental slope and rise? (2) How much do trace metals increase as a result of accumulating drilling mud? (3) In areas where drilling mud components increase in sediments, how long do they remain at elevated concentrations after the drilling is completed?

This study is part of a cooperative, multidisciplinary program that is managed and funded by the U.S. Minerals Management Service. The overall goal is to evaluate potential adverse effects of drilling effluents on bottom-dwelling organisms. Other major components of the program include studies of infaunal and epifaunal communities, hydrocarbon concentrations in sediments and organisms, trace metal concentrations in organisms, sediment texture, and hydrography. These studies will be accomplished under separate contracts awarded to Battelle New England Marine Research Laboratory, Woods Hole Oceanographic Institution (WHOI), and Lamont-Doherty Geological Observatory. Study areas on the continental slope and rise off both the South and North Atlantic states are included in the overall program.

Fourteen station locations were selected on the Mid-Atlantic continental slope and rise (Fig. 1). This station array was established on the premise that drilling mud will be transported by currents over long distances before being deposited. The mean current flow on the continental slope (about 5 cm/s to the west) and currents generated by winds and Gulf Stream rings are

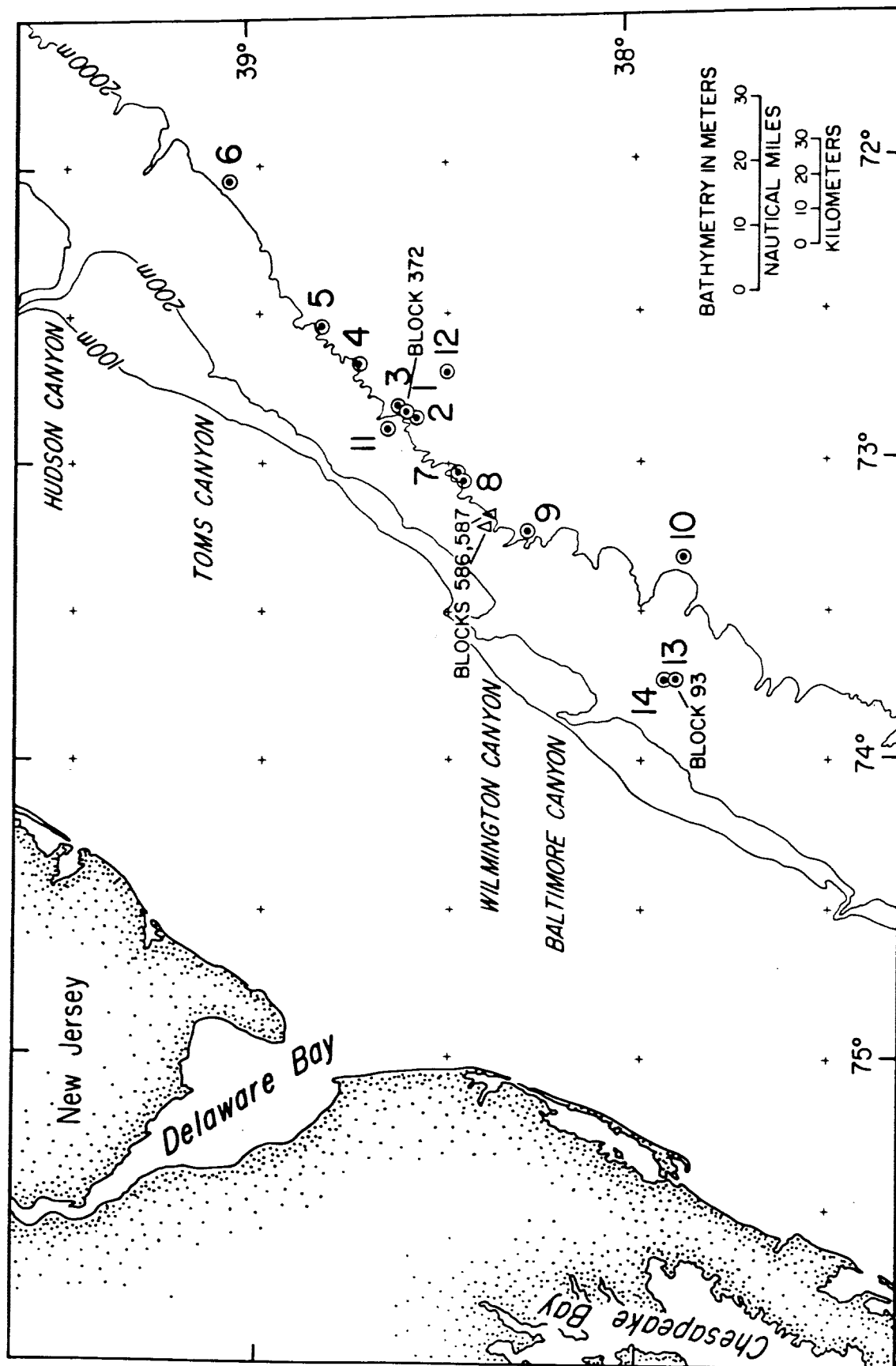


Figure 1. Station locations on the continental slope and rise off the Middle Atlantic states.

generally parallel to isobaths (Beardsley and others, 1985; Butman, 1985). Tidal currents induce periodic flows across isobaths. In response to this current regime, ten of the stations are arranged along the 2,100-m isobath centered around the drilling site at Station 1. Stations 11, 1, and 12 represent a transect across the slope. Station 13 is located 1.3 km southwest of the drill site in Block 93. Station 14 was located on the drilling site in Block 93 and was not sampled during cruises 2 and 3 while the drill rig was on location.

These stations will be sampled three times per year for a two-year period. The first cruise was conducted in March 1984 (Leg 1) and May 1984 (Leg 2). Other cruises were conducted in August 1984, November 1984, and May 1985.

Cruise 1 predated the drilling activity in Lease Blocks 372 and 93. However, drilling had already taken place in this general area at the time of Cruise 1. Two wells had been completed approximately 60 km southwest of Station 1 (Blocks 586 and 587), and 28 wells were drilled on the continental shelf off the Mid-Atlantic states between April 1978 and October 1981.

FIELD SAMPLING AND SAMPLE PREPARATION

Positioning of the ship at each sampling location was based on time delays within the Loran-C navigation network read by a Northstar 6000 receiver (Digital Marine Equipment Corp., Bedford, Mass.). Latitude and longitude values listed in Appendix Table 1 were calculated using updated additional secondary factor corrections (McCullough and others, 1982, 1983). The accuracy of collecting a sample at a given location is more dependent upon wind and current conditions than on the navigation system. Replicate samples collected on two cruises typically fall within a circle having a diameter of 400 m.

A 0.25-m² box core, manufactured by Ocean Instruments, Inc., San Diego, Calif., was used to collect sediment samples for this study. The box was divided into 25 subcores of 0.01 m² each. Three box cores were collected at each station. Two and occasionally three of the subcores from each box core were allocated for trace-metal studies. Surfaces of the aluminum subcores were precoated with teflon as a precaution against metal contamination. At sea, an acid-cleaned round plastic tube, 8.2 cm ID, was pushed into the center of the sediments collected in the teflon subcores, thereby sampling material not in contact with the coring apparatus. These tubes were capped at both ends and frozen. The length of the core samples averaged 24 cm and typically ranged from 19 to 32 cm.

Surficial sediment was sampled by partially extruding the frozen sediment from the core barrel and cutting off the top 2 cm of the sediment with a plastic utensil. To generate a blend from a single station, the material from the upper 2 cm of each of three replicates was thawed, homogenized by stirring and shaking in a closed container, and then subsampled with a syringe constructed of glass and teflon.

On selected samples, sand and coarser material were removed by washing the wet sample through a 60-micron nylon sieve with filtered distilled water. The resultant slurry was dried in an oven having teflon-coated surfaces and a filtered nitrogen atmosphere. Drying temperature for all samples was <70°C.

Cores from selected stations were subsampled in sequential 2-cm depth intervals so that the concentration profile of metals could be measured over increasing sediment depth. The frozen cores were extruded into a holding tray, thawed overnight, and cut into 2-cm depth intervals with plastic utensils. These samples, from which some of the interstitial water had

drained while thawing, were subsequently oven dried. On the basis of trace metal concentrations in interstitial water reported by Lyons and Fitzgerald, 1983, less than 0.05% of the metal in bulk sediment is lost with the drained interstitial water.

All samples prepared for trace-metal analysis were ground using an agate mortar and pestle.

The field numbers (for example, C10123 and C21300) that identify samples in each data table have the following code. The first two characters define the cruise in the Mid-Atlantic region; the second two characters are the station number, the fifth character is the replicate box core number, and the sixth character is the core number within the box core. The use of "00" for the fifth and sixth characters indicates that the sample is a homogenized mixture of subsamples from each of three replicate box cores. Digits in the seventh and eighth space indicate the bottom of a 2-cm thick depth interval; where these are missing, the 0-2 cm interval is sampled. The letter "X" at the end of the field number indicates that the fraction of sediment coarser than 60 micrometers has been removed from the sample.

The USGS prepared thirteen sediment traps for deployment by Science Applications International Corporation (SAIC) near the drilling site in Block 372. Two sizes of traps were used. Ten of the traps were constructed from clear polybuterate tubing 6.6 cm ID and 60 cm length. The other traps were constructed from molded fiberglass. They were cone shaped with a mouth diameter of 50 cm, tapering to a 2-cm-ID sample collection tube. All the trap openings were fitted with baffles to prevent occupation of the traps by fish and other large organisms and to reduce turbulence in the traps. The baffles had a cell diameter of 1 cm and a length of 7.5 cm and consisted of an aramid fiber/phenolic resin (HEXCELL).

TRACE-METAL ANALYSES PROCEDURES

The analyses of trace metals in marine sediments were carried out by the U.S. Geological Survey Branch of Analytical Laboratories, Reston, Va. Concentrations of the following elements were determined: aluminum (Al), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), vanadium (V), and zinc (Zn). The various procedures employed in each of the analyses are detailed below and summarized in Table 1.

Preparation of stock solution A

Exactly 0.5 g of ground bulk sediment or 0.2 g of the fine fraction was added to a covered teflon beaker and digested overnight with 5 mL of HClO_4 , 5 mL of HNO_3 , and 13 mL of HF at approximately 140°C . The covers were removed and the temperature was increased to between 180° and 190°C , first producing fumes of HClO_4 and then evaporating the solution to dryness. The residue was dissolved and diluted to exactly 25 mL with 8 N HCl. This solution is referred to as stock solution A.

Two blanks containing all reagents were analyzed along with samples. All reagents were analyzed for contaminants prior to use, as is always necessary. The Canadian reference sediment standard MESS-1 was analyzed in each set of samples. A series of solutions was prepared that approximated the concentration levels expected in the samples; this series was used as the standard in calibrating the inductively coupled plasma (ICP) spectrometer and atomic absorption (AA) spectrophotometer.

Preparation of stock solution B

Stock solution B was made by adding 10 mL of butyl acetate (distilled to remove impurities such as copper) to 15 mL of stock solution A in a 60-mL separatory funnel. This solution was vigorously agitated by an automatic

Table 1. Summary of analytical conditions.

Element	Instrument	Instrument conditions	Extraction procedure	Procedure determination limit in sample, $\mu\text{g/g}$	Average blanks, as measured in $\mu\text{g/g}$ in solution
Al-----	ICP (argon)-----	308.2 nm FP (Forward power)=1.1 kw Fixed cross flow nebulizer Spectral band width 0.036 nm Observation height 16 mm.	None-----	50	0.02
Ba-----	ICP (argon)-----	455.4 nm FP=1.1 kw Fixed cross flow nebulizer Spectral band width 0.036 nm Observation height 16 mm.	None-----	20	.01
Cd-----	Graphite furnace AA.	110°C dry temperature 250°C char temperature 2100°C atom temperature Regular graphite tube Interrupt gas flow W.l.=228.8 nm Slit=0.7 nm.	Butyl acetate and DDTC.	0.02	.0002
Cr-----	Graphite furnace AA.	110°C dry temperature 850°C char temperature 2700°C atom temperature Pyrolytic tube Normal gas flow (low) W.l.=357.9 nm Slit=0.7 nm.	None-----	2	.003
Cu-----	Graphite furnace AA.	110°C dry temperature 850°C char temperature 2700°C atom temperature Regular graphite tube Interrupt gas flow W.l.=324.7 nm Slit=0.7 nm.	Butyl acetate and DDTC.	1	.005
Fe-----	ICP (argon)-----	259.9 nm FP=1.1 kw Fixed cross flow nebulizer Spectral band width 0.036 nm Observation height 16 mm.	None-----	50	.02
Hg-----	Induction furnace AA.	Wavelength=254 nm Cold vapor AA.	None-----	.005	.005
Mn-----	ICP (argon)-----	257.6 nm FP=1.1 kw Fixed cross flow nebulizer Spectral band width 0.036 nm Observation height 16 mm.	Butyl acetate (removal of iron).	10	.006
Ni-----	Graphite furnace AA.	110°C dry temperature 900°C char temperature 2700°C atom temperature Pyrolytic tube Normal gas flow (low) W.l.=232.0 nm Slit=0.2 nm.	None-----	2	.02
Pb-----	Graphite furnace AA.	110°C dry temperature 500°C char temperature 2700°C atom temperature Regular graphite tube Interrupt gas flow W.l.=283.3 Slit=0.7 nm.	Butyl acetate and DDTC.	1	.02
V-----	Graphite furnace AA.	110°C dry temperature 1000°C char temperature 2800°C atom temperature Pyrolytic curtained tube Normal gas flow (high) W.l.=318.4 nm Slit=0.7 nm.	None-----	2	.002
Zn-----	Flame AA.-----	Oxidizing; air-acetylene flame W.l.=213.9 Slit=0.7 nm.	Butyl acetate-----	1	.01

shaker for six minutes to extract iron. The layers were separated, and the extraction step was repeated with an additional 10 mL of butyl acetate. The aqueous layer was evaporated to dryness at 150°C in a 50-mL beaker. The residue was dissolved and diluted to 25 mL with 1 N HCl.

Barium

The measurements for Ba were made by ICP spectrometry with 2 mL of stock solution A diluted to 4 mL with distilled H₂O.

Aluminum, iron, chromium, nickel, and vanadium

Concentrations of Al and Fe were determined by ICP spectrometry by using 1 mL of stock solution A diluted to 10 mL with distilled H₂O. The measurements for Cr, Ni, and V were made by injecting 20 µL of diluted (1:10) stock solution A into a graphite-furnace AA spectrophotometer.

Lead, copper, and cadmium

Fifteen mL of 0.5-percent (weight:volume) diethyldithiocarbamic acid diethylammonium salt (DDTC) in chloroform were added to 10 mL of solution B in a 60-mL separatory funnel and mixed for 10 minutes by an automatic shaker. The chloroform layer was drained into a 30-mL beaker and the aqueous layer washed with 10 mL of chloroform. The second chloroform layer was combined with the first, and the total volume of chloroform was evaporated to dryness at 90°C. The organic matter was destroyed by adding 0.1 mL of concentrated HNO₃ and was evaporated to dryness. This residue then was dissolved in 2 mL of warm 1 N HCl. The beaker was rinsed four times with 2 mL portions of distilled H₂O, and the solution was transferred to a small polyethylene container. The measurements for Pb, Cu, and Cd were made by injecting 20 µL of the final solution into a graphite-furnace AA spectrophotometer.

Manganese and zinc

The measurements for Mn were made by ICP spectrometry with a solution made by diluting 2 mL of stock solution B to 4 mL with H₂O. Zinc was measured by flame AA directly from stock solution B.

Mercury

Mercury concentration was determined on a separate portion of the sample. Two hundred milligrams of sediment were decomposed in a 1-oz teflon screw-top vial with 2 mL of concentrated HNO₃ (J. T. Baker Chemical Co.) and 2 mL of HClO₄ (G. Frederick Smith Chemical Co. (GFS) double distilled from Vycor, a pure silica glass). The mixture was heated in a capped vial until the solution reached 200°C. The solution was then heated with the cap off for about 45 minutes, after which the samples were removed from the heat source. Immediately, 1 mL of concentrated HNO₃ was added; the vial was filled with H₂O and capped tightly until used. The sample solution then was added to a flask containing 125 mL of H₂O and 4 mL of 10-percent (weight:volume) SnCl₂ in 20-percent HCl. Nitrogen was passed through the solution to remove elemental Hg, which was collected on gold foil located in the center of the coils of an induction furnace. Activation of the furnace released the Hg, which was measured by a cold-vapor AA technique. Blanks, standard rocks, and internal sediment standards were analyzed for each set of samples. A series of solutions was prepared that had the same Hg concentration range expected in the samples.

TEXTURAL ANALYSIS PROCEDURES

Sediment samples selected from different depth horizons within the box cores were analyzed for texture by the standard pipette method (Folk, 1974). The specific procedures were essentially identical to those used by other

contractors within this program (Battelle and others, 1985). The textural results are reported in phi units ($-\log_2 D$) where D is the grain diameter in mm.

ANALYTICAL ACCURACY AND PRECISION

Analytical accuracy was determined by analyzing rock standard MESS-1. With the exception of Cr, the metals are within one or, at most, two standard deviations of the "best value" determined for this sediment standard (Table 2). A new fine-grained sediment standard (B series, Table 2) established for the Georges Bank Monitoring Program (Bothner and others, 1983) will also be used during this program.

We have identified a systematic difference in the Cr data generated on standards which followed installation of a new pyrolytic tube in the graphite furnace. The first 6 Cr values for sediment standard MESS (Table 2) were determined using a graphite tube, and averaged $47.7 \text{ ppm} \pm 0.5 \text{ ppm}$. These determinations were made at the same time as samples from cruises 1 and 2 and some samples from cruise 3. The last 5 determinations, using a pyrolytic tube, average $61.6 \text{ ppm} \pm 2.2 \text{ ppm}$ and correspond to remaining samples from cruises 3 and 4. The latter value is within the published acceptable range for Cr ($71 \text{ ppm} \pm 11 \text{ ppm}$).

Using a new graphics display, we were recently able to observe the Cr peak shapes of sediment standards and liquid standards. With the graphite tube, which is more porous than the pyrolytic tube, sediment standards had a broader peak than liquid standards. The interpretation is that some of the analyzed solution evaporated within the fabric of the graphite tube and that the residual salts slightly retarded the release of Cr during the heating cycle. The liquid standards having less salt were not affected. Both liquid

Table 2A. - Analysis of sediment standard and replicate sediment samples.

Sediment Standard	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
MESS-1-----	5.30	280	0.46	47	27	2.9	470	35	28	70	170
	5.70	260	.43	48	21	2.9	470	31	31	71	180
	5.40	260	.45	48	23	2.8	480	37	29	73	200
	5.30	280	.46	47	27	2.9	470	35	28	70	170
	5.70	260	.43	48	21	2.9	470	31	31	71	180
	5.40	260	.45	48	23	2.8	480	37	29	73	200
	5.41	258	.48	65	23	2.78	469	35	31	85	174
	4.89	259	.42	61	25	2.80	483	31	25	80	178
	5.06	259	.41	61	28	2.85	489	34	27	74	186
	5.38	257	.50	59	25	2.81	481	31	32	85	187
	5.21	256	.40	62	24	2.79	476	34	32	85	184
\bar{x} -----	5.29	261	.44	56.4	24.5	2.83	477	33.5	29.4	77.9	182
σ -----	.24	8	.03	7.4	2.3	.05	7	2.3	2.6	6.6	9
CV(%) ¹ -----	4.6	3.0	7.9	13	9.3	1.7	1.5	6.8	8.7	8.5	5.1
Best value ²	5.8	270	.59	71	25	3.0	513	30	34	72	191
σ -----	.2		.1	11	4	.2	25	3	6	5	17
Sediment Standard	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
B-10 ³	3.4	280	.066	31	6.3	1.6	290	12	17	40	40
B-11	3.7	270	.060	34	5.8	1.7	300	10	15	38	42
B-12	3.5	270	.063	32	6.0	1.6	290	20	15	38	40
\bar{x} -----	3.53	273	.063	32.3	6.0	1.63	293	14	15.7	38.7	40.7
σ -----	.15	6	.003	1.5	.3	.06	6	5.3	1.2	1.2	1.2
CV(%) ¹ -----	4.2	2.2	4.8	4.6	.1	3.7	2.0	37.9	7.6	3.1	2.9
Sample Replicate	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C11311	5.7	420	.095	61	27	3.2	810	50	24	87	76
W-228624	5.7	430	.075	58	27	3.2	800	50	22	87	76
	5.7	420	.083	61	26	3.2	800	48	22	90	76
	5.7	410	.095	60	26	3.2	780	49	22	90	76
	5.7	420	.091	62	27	3.2	790	49	22	87	78
\bar{x} -----	5.7	420	.09	60.4	26.6	3.2	796	49.2	22.4	88.2	76.4
σ -----	0	7	.01	1.5	.5	0	11	.8	.9	1.6	.9
CV(%) ¹ -----	0	1.7	11.1	2.5	7.9	0	1.2	1.6	4.0	1.8	1.2
Sample Replicate	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C21300	6.3	430	.075	58	24	3.4	790	34	18	120	91
W-228542	6.3	420	.075	60	23	3.4	780	36	16	120	90
	6.4	420	.071	60	24	3.4	800	38	16	110	90
	6.4	430	.063	60	23	3.4	810	36	16	110	91
	6.3	430	.066	60	23	3.3	790	34	16	120	90
\bar{x} -----	6.34	426	.07	59.6	23.4	3.4	794	35.6	16.4	116	90.4
σ -----	.06	5	.01	.9	.5	0	11	1.7	.9	5.5	.5
CV(%) ¹ -----	.9	1.2	14.3	1.5	2.1	0	1.4	4.8	5.5	4.7	.5
Sample Replicate	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C20131	5.0	390	.042	50	16	3.0	670	40	14	90	75
W-228517	4.9	390	.048	50	16	2.9	670	42	12	83	73
	5.0	380	.048	51	16	3.0	640	42	12	90	73
	5.0	380	.050	50	16	3.0	610	40	12	83	73
	5.0	410	.042	50	16	3.0	650	41	13	87	75
\bar{x} -----	4.98	390	.046	50.2	16	2.98	648	41	12.6	86.6	73.8
σ -----	.05	12	.004	.4	0	.05	25	1	.9	3.5	1.1
CV(%) ¹ -----	1.0	3.1	8.7	.8	0	1.7	3.9	2.4	7.1	4.0	1.5

¹ Coefficient of variation.² Values reported by the Marine Analytical Chemistry Standards Program, National Research Council, Canada.³ A fine-grained sediment standard collected from station 13 of the Georges Bank Monitoring Program (Bothner and others, 1983).

Table 2B. - Analysis of replicate sediment samples from Cruises 3 and 4.

Sample Replicate	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C302002X	5.40	418	0.041	72	22	3.03	0.030	686	50	12	94	76
	5.43	418	.050	70	22	3.06	.030	686	47	13	98	76
	5.41	420	.041	69	23	3.04	.027	712	45	13	90	76
	5.50	416	.050	69	22	3.10	.030	702	45	12	98	76
	5.43	413	.058	72	23	3.05	.030	704	50	12	98	75
\bar{x} -----	5.43	417	.048	70.4	22.4	3.06	.029	698	47.4	12.4	95.6	75.8
σ -----	.04	3	.007	1.5	.5	.03	.001	12	2.5	.5	3.6	.4
CV(X) ¹ ----	.7	.6	15	2.1	2.4	.9	4.6	1.7	5.3	4.4	3.7	.6
C4012122	5.52	423	.071	80	23	3.03	.040	360	36	9.6	109	75
	5.41	420	.080	82	23	3.00	.040	360	36	10	104	75
	5.39	418	.071	80	22	2.98	.040	354	36	10	109	75
	5.39	416	.080	80	23	2.99	.040	362	39	9.6	104	76
	5.42	416	.075	80	23	3.00	.040	361	39	9.6	109	75
\bar{x} -----	5.43	419	.075	80.4	22.8	3.00	.04	359	37.2	9.8	107	75.2
σ -----	.05	3	.004	.9	.4	.02	0	3	1.6	.2	3	.4
CV(X) ¹ ----	1	.7	6	1.1	2	.6	0	.9	4.4	2.2	2.6	.6

¹Coefficient of variation.

and sediment standards give the same shape with the pyrolytic tube because it is glazed and non-porous.

The significance of this improvement in technique is to cause an artificial difference in the Cr results between cruises 1-4 as shown in Table 5. Until the final report, these differences should be interpreted as being within analytical error. These differences can be corrected by basing the Cr signal on the sediment standards which were run with each batch of samples rather than the liquid standards. We will carry out this operation for the final report after checking the accuracy of the approach by reanalyzing a representative number of samples from Cruise 1 using the new technique.

The concentration of V in the sediment standard MESS (Table 2A) shows a much smaller increase corresponding to the change in procedure, but there is no consistent change in results from samples from the same station on different cruises. We will be carefully evaluating the V results before the final report.

Analytical precision was determined by periodically analyzing replicate aliquots taken from a single sample. Coefficients of variation shown in Table 2 indicate that the standard deviations are typically less than 10 percent of the mean value, except for concentrations at or near the detection limit of the method. Analytical precision for Ba averages 1.8 percent (range 0.6 - 3.0 percent) for 5 replicates from each of 3 samples.

During the early phases of this program, we evaluated the metal concentrations in surface sediments that were in contact with different materials used in the box of the box corer. Mr. George Hampson, WHOI, suggested this experiment and provided the carefully collected samples.

Metal concentrations in sediments from the center of a teflon-coated subcore (those not in contact with the sampler) were compared to

concentrations in sediments in contact with the teflon coating and in contact with the uncoated aluminum (Table 3). Bulk sediments and the separated fine fraction were compared. We found that the concentrations of Ba and Cr, the metals most likely to indicate the presence of drilling mud in sediments, were not contaminated by contact with the walls of the box corer. In the bulk sediments, vanadium may be slightly higher in the samples collected from the edge of the teflon-coated subcore compared to the other samples. In the fine fraction, the lead values from the edges of the subcores are about 40 percent higher than the sediment not in contact with the box-core material.

The material collected at the edges of the subcore probably represent the worst case for contamination from the material used to construct the box-core sample chamber. The sediment that is routinely removed from the subcore for trace-metal analysis excludes the material in contact with the wall of the subcore. We therefore conclude that contamination from the walls of the box core is insignificant. This test does not rule out the possibility that metal contamination could occur from flakes of material falling onto the sediment surface from the coring apparatus above the sample box, but such contamination would be random and severe and should be obvious from the chemical analysis. We have not yet recorded any spurious values that would suggest this is a problem.

RESULTS AND DISCUSSION

Within-station variability

We determined the variability of metal concentrations within an individual box core and between replicate box cores taken at the same station (Table 4A-E). In samples unaffected by drilling muds, the within-box core variability is typically less than 4 percent, and the within-station

Table 3. - Chemical analyses of replicate samples collected from different areas of a single box core.

[Samples A, B, and C from center of a teflon-coated subcore (assumed to be the least contaminated); D, E, and F in contact with the side of teflon-coated subcore; G, H, and I in contact with the side of aluminum subcore. Field no. ending in X means size fraction finer than 60 μ m analyzed.]

Field no.	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
SA21A-----	W-226341	1.8	120	0.068	26	8.4	1.1	0.02	120	11	5	12	30
SA21B-----	W-226342	1.8	130	.140	26	8.6	1.0	.02	120	11	5	17	32
SA21C-----	W-226343	1.9	130	.180	28	12	1.1	--	120	13	6	16	32
\bar{x} -----		1.83	127	.13	26.7	9.7	1.07	.02	120	11.7	5.3	15	31
σ -----		.06	5.8	.06	1.2	2.0	.06	0	0	1.2	.6	2.6	1.2
CV(X) ¹ ----		3.2	4.6	44	4.3	21	5.4	0	0	9.9	10.8	17.6	3.7
SA21D-----	W-226344	1.9	130	.150	26	10	1.1	.02	130	12	7	20	33
SA21E-----	W-226345	1.9	130	.130	26	8.6	1.1	.02	130	11	5	21	32
SA21F-----	W-226346	1.9	130	.088	29	7.8	1.1	.02	150	12	6	23	32
\bar{x} -----		1.9	130	.12	27.0	8.8	1.1	.02	137	11.7	6.0	21	32
σ -----		0	0	.03	1.7	1.1	0	0	12	.6	1.0	1.5	.6
CV(X) ¹ ----		0	0	26	6.4	13	0	0	8.4	4.9	16.7	7.2	1.8
SA21G-----	W-226347	1.8	120	.083	26	10	1.1	.02	160	11	6	10	30
SA21H-----	W-226348	1.8	130	.110	25	7.5	1.0	.02	130	11	5	12	30
SA21I-----	W-226349	1.8	130	.130	26	8.0	1.0	.02	120	11	4	10	30
\bar{x} -----		1.80	127	.11	25.7	8.5	1.03	.02	137	11	5.0	11	30
σ -----		0	5.8	.02	.6	1.3	.06	0	21	0	1.0	1.2	0
CV(X) ¹ ----		0	4.6	22	2.2	16	5.6	0	15	0	20	10.8	0
SA21AX-----	W-226350	2.8	160	.085	35	13	1.28	.04	149.5	20	8	36	48.0
SA21BX-----	W-226351	2.8	158	.105	35	14	1.26	.04	147.5	20	7	33	44.2
SA21CX-----	W-226352	2.7	158	.148	35	14	1.27	--	147.7	20	6	33	44.3
\bar{x} -----		2.79	159	.11	35	14	1.27	.04	149	20	7.0	34	45.3
σ -----		.05	1.2	.03	0	.6	.01	0	1.2	0	1.0	1.7	2.3
CV(X) ¹ ----		1.8	0.7	28	0	4.2	.8	0	.8	0	14.3	5.1	5.1
SA21DX-----	W-226353	2.8	161	.098	35	9.8	1.29	.05	150.3	19	11	33	48.3
SA21GX-----	W-226354	2.8	160	.097	35	13	1.28	.04	192.5	20	10	37	48.1
\bar{x} -----		2.78	160	.10	35	11	1.28	.04	172	19.5	10.5	35	48.2
σ -----		.01	.7	0	0	2.3	.01	.01	30	.7	.7	2.8	.1
CV(X) ¹ ----		.2	.4	.7	0	20	.6	16	18	3.6	6.7	8.1	.2

¹Coefficient of variation.

Table 4A. - Comparison of within-station variability to within box core variability at Station 1, Cruise 1.

Field no.	Top (cm)	Btm (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C10111	0	2	W-228607	5.2	400	0.110	54	27	2.9	0.03	750	39	12	78	63
C10121	0	2	W-228608	5.5	430	.096	56	26	3.0	.02	770	47	12	78	70
C10131	0	2	W-228611	5.4	420	.071	56	25	2.9	.02	720	41	15	80	70
\bar{x}				5.37	416	.092	55.3	26	2.93	.02	747	42.3	13	79	68
σ				.15	15	.020	1.1	1	.06	0	25	4.2	1.7	1.1	4.0
CV%				2.8	3.7	21	2.1	3.8	2.0	6.4	3.4	9.8	13	1.5	6.0
C10121	0	2	W-228608	5.5	430	.096	56	26	3.0	.02	770	47	12	78	70
C10122	0	2	W-228609	5.5	430	.046	58	28	3.0	.02	800	45	14	84	71
C10123	0	2	W-228610	5.5	430	.063	58	28	3.0	.02	860	46	16	90	73
\bar{x}				5.5	430	.068	57.3	27.3	3.0	.02	810	46.0	14	84	71
σ				0	0	.025	1.0	1.0	0	0	46	1.0	2	6	1.5
CV%				0	0	37	1.8	3.7	0	0	5.7	2.2	14	7.1	2.1

Table 4B. - Comparison of within station variability to within box core variability at Station 1, Cruise 2.

Field no.	Top (cm)	Btm (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C20111	0	2	W-228513	5.2	420	0.055	52	14	2.9	0.03	710	50	12	90	83
C20121	0	2	W-228516	4.7	410	.042	48	15	2.7	.04	590	40	13	80	73
C20131	0	2	W-228517	5.0	390	.046	50	16	3.0	.04	650	41	13	86	74
\bar{x}				4.97	407	.048	50	15	2.87	.04	650	43.7	13	86	77
σ				.25	15	.006	2	1.0	.15	.01	60	5.5	.6	5.1	5.5
CV%				5.1	3.8	14	4	6.7	5.3	14	9.2	13	4.5	5.9	7.2
C20111	0	2	W-228513	5.2	420	.055	52	14	2.9	.03	710	50	12	90	83
C20112	0	2	W-228514	5.2	430	.048	54	17	3.0	.03	790	52	16	87	80
C20113	0	2	W-228515	5.2	430	.042	52	19	2.9	.05	750	46	14	90	80
\bar{x}				5.2	427	.048	52.7	16.7	2.93	.04	750	49.3	14	89	81
σ				0	5.8	.065	1.2	2.5	.06	.01	40	3.1	2	1.7	1.7
CV%				0	1.4	13	2.2	15	2.0	31	5.3	6.2	14	1.9	2.1

1 Coefficient of variation.

Table 4C. - Comparison of within station variability to within box core variability at Station 1, Cruise 3.

Field no.	Top (cm)	Btm (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C30111	0	2	W-229828	5.08	493	0.041	62	22	2.87	0.03	565	41	12	90	73
C30121	0	2	W-229831	5.27	427	.041	64	23	2.93	.03	652	44	12	94	75
C30131	0	2	W-229832	5.19	401	.075	62	22	2.87	.02	343	40	12	94	70
\bar{x}				5.18	440	.052	62.7	22.3	2.89	.03	520	41.7	12.0	92.7	72.7
σ				0.09	47.4	.020	1.2	.6	.03	.01	159	2.1	.0	2.3	2.5
CV%				1.84	10.8	38	1.8	2.6	1.2	22	31	5.0	.0	2.6	3.5
C30111	0	2	W-229828	5.08	493	.041	62	22	2.87	.03	565	41	12	90	73
C30112	0	2	W-229829	5.17	412	.055	66	22	2.90	.02	507	42	10	84	75
C30113	0	2	W-229830	5.13	400	.041	75	22	2.88	.02	513	43	12	89	73
\bar{x}				5.13	435	.046	67.7	22.0	2.88	.02	528	42.0	10.7	87.8	73.7
σ				.04	50.6	.008	6.7	0.0	0.01	.01	31.9	1.0	1.2	3.2	1.2
CV%				.88	12	18	9.8	0.0	0.53	25	6.0	2.4	11	3.7	1.6

Table 4D. - Comparison of within station variability to within box core variability at Station 14, Cruise 4.

Field no.	Top (cm)	Btm (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C41411	0	2	W-231772	5.60	389	0.071	81	21	3.10	0.04	689	36	20	87	86
C41421	0	2	W-231773	5.59	411	.055	79	21	3.15	.04	832	42	18	82	88
C41431	0	2	W-231774	5.62	386	.071	79	23	3.13	.04	710	39	26	105	85
\bar{x}				5.60	395	.066	79.7	21.7	3.13	.04	744	39.0	21.3	91.3	86.3
σ				.01	13.6	.009	1.2	1.3	.02	.00	77.2	3.0	4.2	12.1	1.5
CV%				.27	3.5	14	1.5	5.3	.80	.00	10	7.7	20	13	1.8
C41411	0	2	W-231772	5.60	389	.071	81	21	3.10	.04	689	36	20	87	86
C41421	0	2	W-231775	5.60	397	.055	80	22	3.07	.04	593	36	18	87	88
C41431	0	2	W-231776	5.66	386	.038	85	21	3.11	.03	577	39	16	96	88
\bar{x}				5.62	391	.055	82.0	21.3	3.09	.04	620	37.0	18.0	40.0	87.3
σ				.03	5.7	.016	2.7	.6	.02	.01	60.6	1.7	2.0	5.2	1.2
CV%				.62	1.5	30	3.2	2.7	.67	16	9.8	4.7	11	5.8	1.3

1 Coefficient of variation.

Table 4E. - Within station variability for Cruise 1, Stations 5 and 13; Cruise 2, Stations 2, 4, 6 and 13; Cruise 3, Stations 6 and 13; Cruise 4, Stations 1 and 13.

Field no.	Top (cm)	Bot (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C20211	0	2	W-228615	5.0	370	0.075	50	18	2.7	0.01	300	34	8.3	74	58
C20221	0	2	W-228616	4.6	360	.058	44	19	2.5	.01	440	30	15	66	56
C20231	0	2	W-228617	4.8	380	.058	46	24	2.6	.02	610	34	15	74	60
\bar{x}				4.8	370	.06	46.7	20.3	2.6	.01	517	32.7	13	71	58
σ				.2	10	.01	3.1	3.2	.1	0	86	2.3	3.9	4.6	2.0
CV%				4.2	2.7	15	6.5	16	3.8	14	17	7.1	30	6.5	3.4
C20411	0	2	W-228618	4.9	380	.076	48	20	2.6	.01	490	33	13	74	60
C20421	0	2	W-228619	5.2	410	.063	52	23	2.8	.02	430	42	11	84	63
C20431	0	2	W-228620	4.6	370	.061	44	20	2.4	.01	420	32	12	70	51
\bar{x}				4.9	387	.07	48	21.0	2.6	.01	447	35.7	12	76	58.0
σ				.3	21	.01	4.0	1.7	.2	0	38	5.5	1.0	7.2	6.2
CV%				6.1	5.4	12	8.3	8.2	7.7	11	8.5	15	8.3	9.5	11
C10511	0	2	W-228612	5.5	440	.066	58	28	3.0	.02	840	45	15	84	73
C10521	0	2	W-228613	5.5	430	.096	60	26	2.9	.02	830	49	15	87	70
C10531	0	2	W-228614	5.5	420	.075	60	29	3.0	.02	700	46	17	86	71
\bar{x}				5.5	430	.08	59.3	27.7	2.97	.02	790	46.7	16	86	71
σ				0	10	.02	1.2	1.5	.06	0	78	2.1	1.2	1.5	1.5
CV%				0	2.3	19	1.9	5.5	1.9	0	9.9	4.4	7.5	1.8	2.2
C20611	0	2	W-228621	5.1	420	.075	50	25	2.8	.02	840	40	14	80	65
C20621	0	2	W-228622	5.3	430	.091	56	24	2.9	.02	720	42	13	84	65
C20631	0	2	W-228623	5.2	400	.066	52	27	2.8	.02	810	44	16	87	61
\bar{x}				5.2	417	.077	52.7	25.3	2.83	.02	790	42	14	84	64
σ				.1	15	.013	3.1	1.5	.06	0	62	2.0	1.5	3.5	2.3
CV%				1.9	3.7	16	5.8	6.0	2.0	6.0	7.9	4.8	11	4.2	3.6
C30611	0	2	W-229833	4.74	368	.063	55	18	2.57	.02	537	33	10.0	84	66
C30621	0	2	W-229834	5.13	406	.050	64	23	2.82	.02	674	41	12.0	94	71
C30631	0	2	W-229835	5.24	409	.045	69	22	3.01	.02	1,202	47	13.0	94	73
\bar{x}				5.04	394	.053	62.7	21.0	2.80	.02	804	40.3	11.7	90.7	70.0
σ				.26	22.8	.009	7.1	2.6	.22	.00	351	7.02	1.5	5.8	3.6
CV%				5.2	5.8	18	11	13	7.9	.00	44	17	13	6.4	5.2
C11311	0	2	W-228624	5.7	420	.088	60	27	3.2	.03	800	49	22	88	76
C11321	0	2	W-228625	5.7	410	.090	58	22	3.1	.04	590	46	22	84	73
C11331	0	2	W-228626	5.9	440	.095	62	25	3.3	.03	410	50	24	94	78
\bar{x}				5.77	423	.09	60	24.7	3.20	.03	600	48.3	23	89	76
σ				.12	15	0	2.0	2.5	.10	.01	200	2.1	1.2	5.0	2.5
CV%				2.0	3.6	4.0	3.3	10	3.1	19	32	4.3	5.1	5.6	3.3

1 Coefficient of variation.

Table 4E. - Within station variability for Cruise 1, Stations 5 and 13; Cruise 2, Stations 2, 4, 6 and 13; Cruise 3, Stations 6 and 13; Cruise 4, Stations 1 and 13-Continued.

Field no.	Top Btm (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C21311	0	2	W-228510	5.8	430	0.063	58	22	3.4	0.05	900	54	21	100
C21321	0	2	W-228511	5.8	430	.066	59	22	3.3	.04	730	54	11	100
C21331	0	2	W-228512	5.5	410	.042	60	18	3.2	.06	720	54	22	95
\bar{x}			5.7	423	.06	59	20.7	3.30	.05	780	54	18	98	96
σ			.17	11	.01	1.0	2.3	.10	.01	100	0	6.1	2.9	3.6
CV%			3.0	2.7	23	1.7	11	3.0	20	13	0	34	2.9	3.8
C31311	0	2	W-229836	5.45	425	.066	69	24	3.10	.03	611	50	25.0	104
C31321	0	2	W-229837	5.55	428	.066	67	23	3.20	.03	665	50	18.0	95
C31331	0	2	W-229838	5.65	417	.075	68	23	3.29	.03	1,171	49	21.0	95
\bar{x}			5.55	423	.069	68.0	23.3	3.20	.03	816	49.7	21.3	98.0	82.7
σ			.10	5.7	.005	1.0	.6	.09	.00	309	.6	3.5	5.2	2.5
CV%			1.8	1.3	7.5	1.5	2.5	3.0	.00	38	1.2	17	5.3	3.0
C40111	0	2	W-231766	5.32	424	.038	78	24	2.97	.03	717	34	14.0	87
C40121	0	2	W-231767	5.14	400	.055	74	21	2.81	.02	810	32	12.0	82
C40131	0	2	W-231768	5.31	418	.083	78	24	2.94	.02	704	34	13.0	87
\bar{x}			5.26	414	.059	76.7	23.0	2.91	.02	744	33.3	13.0	85.3	79.3
σ			.10	12.5	.023	2.3	1.7	.08	.01	57.8	1.2	1.0	2.9	6.0
CV%			1.9	3.0	39	3.0	7.5	2.9	25	7.8	3.5	7.7	3.4	7.6
C41311	0	2	W-231769	5.63	412	.066	81	26	3.15	.03	783	40	20.0	92
C41321	0	2	W-231770	5.70	404	.075	83	26	3.30	.04	904	43	22.0	110
C41331	0	2	W-231771	5.72	399	.310(?)83	24	24	3.24	.05	655	40	22.0	82
\bar{x}			5.68	405		82.3	25.3	3.23	.04	781	41.0	21.3	94.7	98.7
σ			.05	6.6		1.2	1.2	.07	.01	124	1.7	1.2	14.2	3.2
CV%			.83	1.6		1.4	4.6	2.3	25	16	4.2	5.4	15	3.3

¹Coefficient of variation.

variability is less than 6 percent. From this information, we conclude that the distribution of Ba is fairly uniform within circles on the continental slope having a diameter of 400 m. This size circle in most cases contains all the replicate box cores at a given station. The samples from Station 1, Cruise 3 show a higher coefficient of variation than other stations because the replicates include one sample which has elevated Ba, presumably caused by the addition of drilling mud.

Distribution of metals in surface sediments

We have plotted the concentration of metals, organic carbon, and textural parameters for each station occupied during Cruise 1 in the order of their latitude from north to south (Fig. 2A, B, C, and D and Table 5). Organic carbon and textural data were provided by the Battelle-WHOI contractors for this program.

The concentrations of metals in these sediments are the same or lower than they are in average shales from various locations around the world (Krauskopf, 1967), a similarity which suggests that these predrilling sediments had not been contaminated prior to this program. The variation in metal concentrations is small, generally within a factor of 2 over the entire study area.

The variation in concentration of metals, organic carbon, and clay is very similar from station to station. The close correlation among these variables can be explained by the varying proportion of clay in the sediment, which is expected to contain the highest concentration of the metals analyzed. At Station 11, the clay fraction, organic carbon, and most of the metals are at higher concentrations than those at adjacent stations shown in Figure 2. At Station 12, we observed the lowest concentrations of clay, organic carbon, and most of the metals.

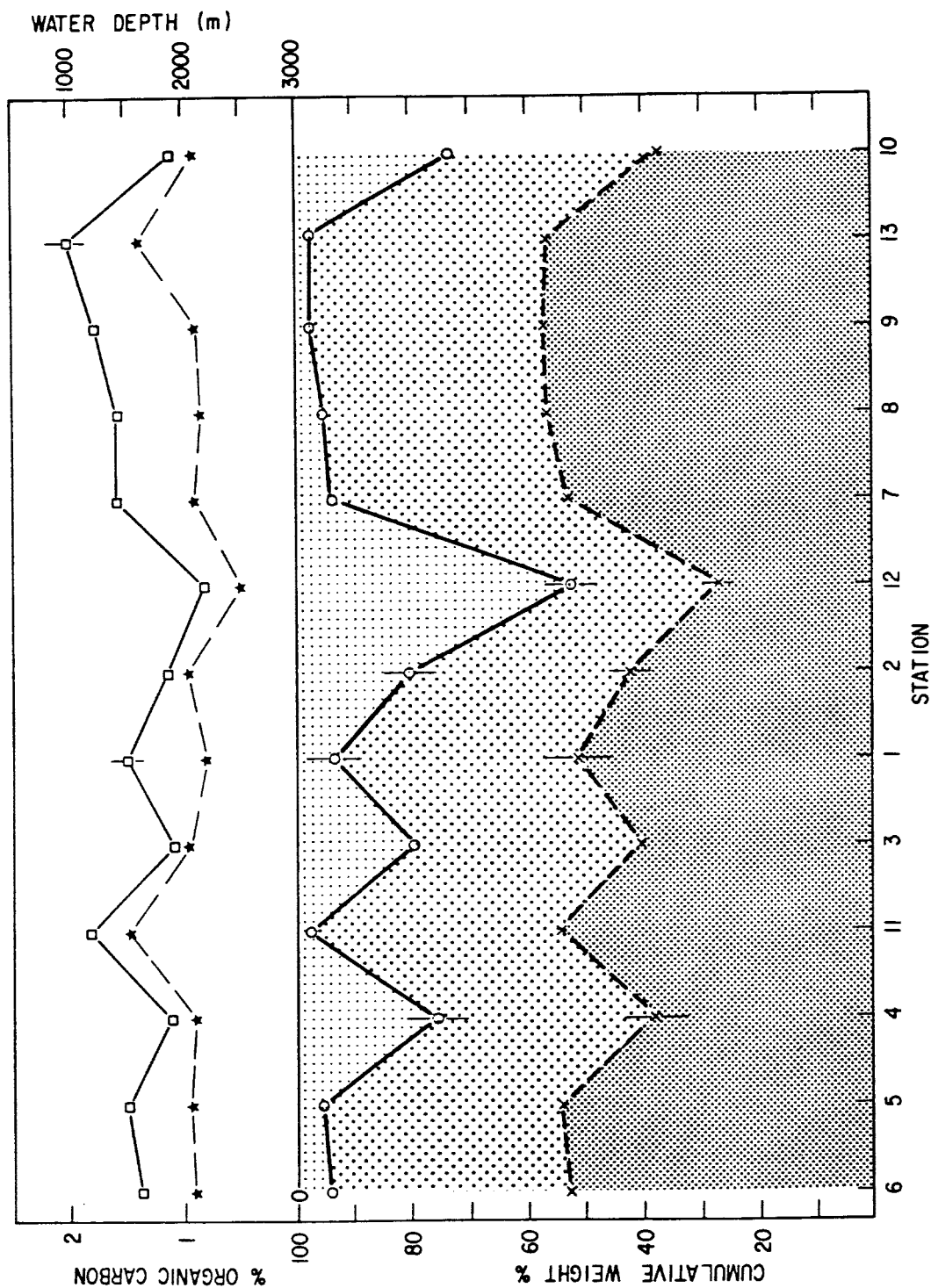


Figure 2A. Average concentration of organic carbon (□ in percent) and water depth (★ in meters) at stations from Cruise 1 listed from north to south. Error bars represent standard deviation among three replicates.

2B. Average concentrations of clay (■), silt (□), and sand (□) in cumulative weight percent at stations from Cruise 1 listed from north to south. Error bars represent standard deviation among three replicates.

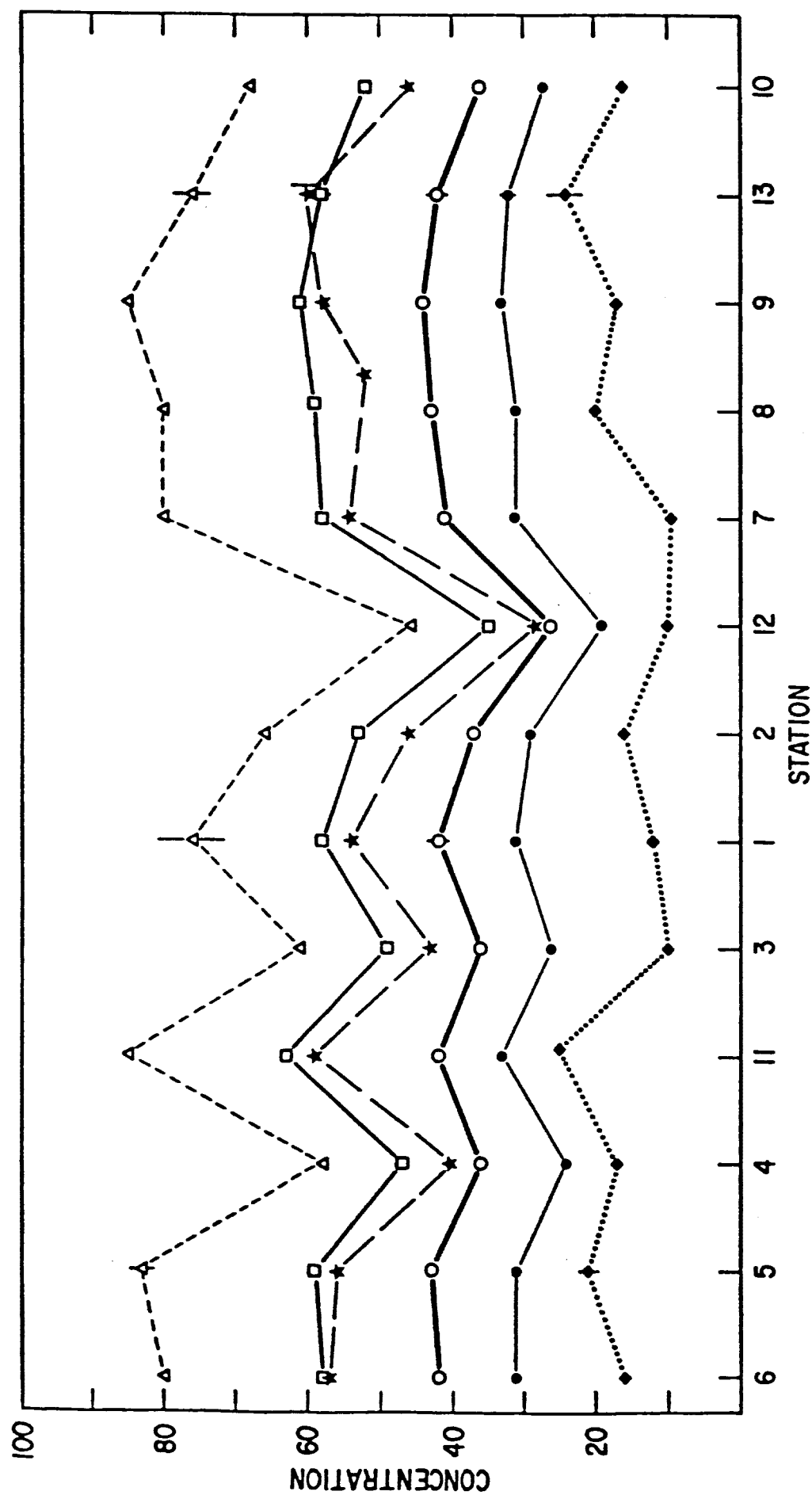


Figure 2C: Concentrations of metals in station blends from Cruise 1. Stations listed from north to south. (Al, \square $\% \times 10^{-1}$; Ba, \circ ppm $\times 10^{-1}$; Cr, \star ppm; Cu, \diamond ppm; Fe, \bullet $\% \times 10^{-1}$; Zn, \triangle ppm.) Error bars represent standard deviation among three replicates at Stations 1, 5, and 13. Where error bars do not appear at these stations, error is within the area of the symbol.

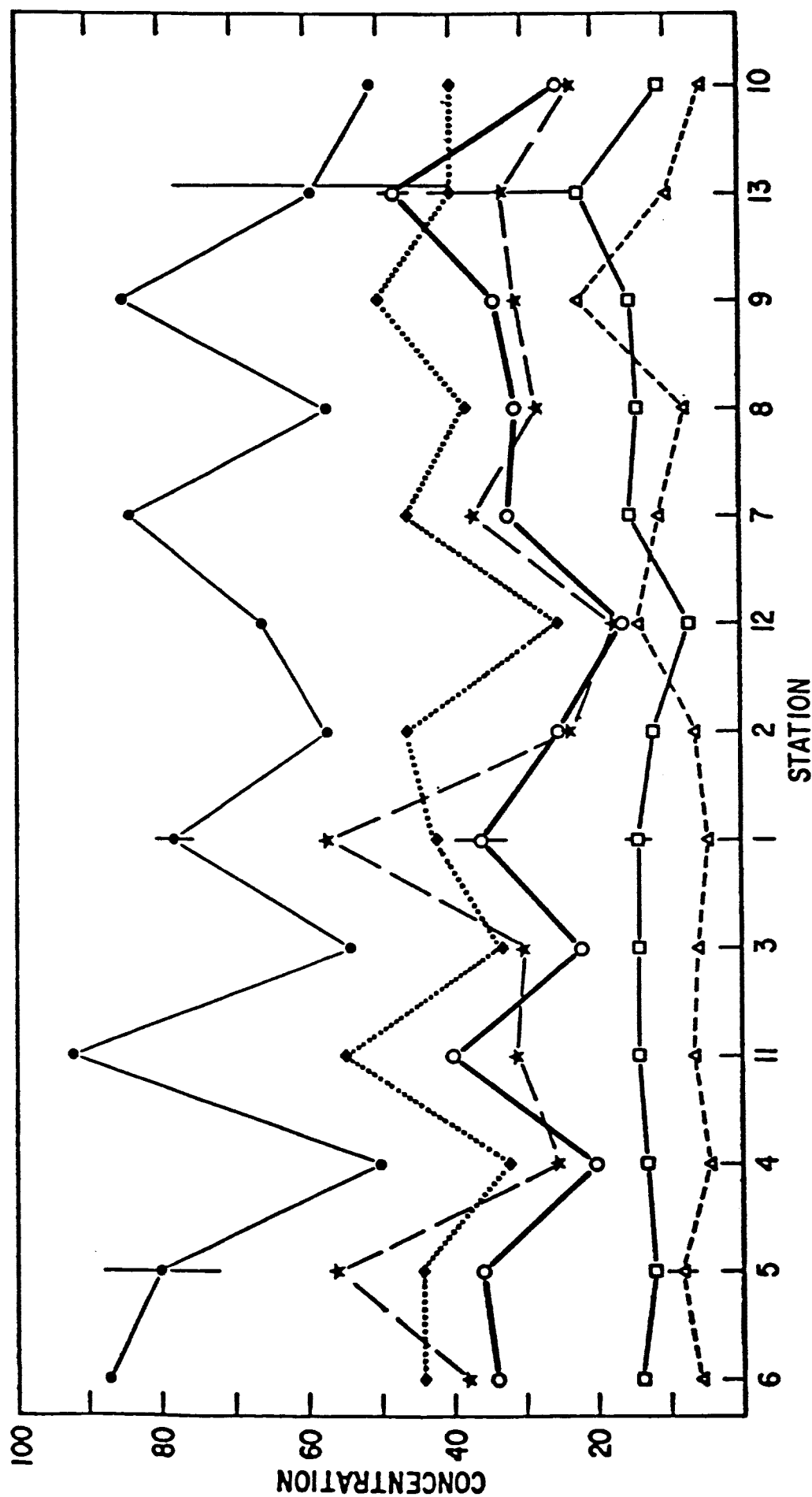


Figure 2D. Concentration of metals in station blends from Cruise 1. Stations listed from north to south. (Cd, Δ ppm $\times 10^2$; Hg, \star ppm $\times 10^3$; Mn, \bullet ppm $\times 10^3$; Ni, \circ ppm; Pb, \square ppm; V, \blacklozenge ppm $\times 1/2$.) Error bars represent standard deviation among three replicates at Stations 1, 5, and 13. Where error bars do not appear at these stations, error is within the area of the symbol.

Table 5. - Chemical analyses of station blends.

Field no.	Top (cm)	Bottom (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C10100	0	2	W-228518	5.80	420	0.045	54	12	3.10	0.06	780	36	14	83	76
C20100	0	2	W-228530	5.50	440	.060	52	14	3.00	.03	670	30	12	91	75
C30100	0	2	W-229811	5.25	444	.041	63	18	2.97	.03	519	36	13	90	71
C40100	0	2	W-231781	5.30	415	.100	74	22	2.89	.02	750	36	12	87	73
C10200	0	2	W-228519	5.30	370	.063	46	16	2.90	.02	570	25	12	91	66
C20200	0	2	W-228531	5.20	370	.050	44	15	2.70	.03	550	27	14	83	65
C30200	0	2	W-229812	4.82	386	.045	58	17	2.72	.03	607	30	11	84	63
C40200	0	2	W-231782	5.14	374	.055	78	19	2.77	.02	712	32	12	87	68
C10300	0	2	W-228520	4.90	360	.060	43	10	2.60	.03	540	22	14	66	61
C20300	0	2	W-228532	4.80	340	.045	38	13	2.40	.02	700	25	14	81	58
C30300	0	2	W-229813	4.20	335	.120	46	13	2.25	.02	439	24	10	76	50
C40300	0	2	W-231783	4.28	319	.028	62	16	2.24	.02	448	22	9	68	55
C10400	0	2	W-228521	4.70	360	.045	40	17	2.40	.03	500	20	13	63	58
C20400	0	2	W-228533	5.20	390	.071	44	17	2.60	.02	470	31	12	91	65
C30400	0	2	W-229814	4.49	365	.025	52	14	2.43	.02	594	30	10	94	56
C40400	0	2	W-231784	4.93	374	.042	72	18	2.65	.02	584	32	9.1	82	61
C10500	0	2	W-228522	5.90	430	.083	56	21	3.10	.06	800	36	12	87	83
C20500	0	2	W-228534	5.80	430	.060	54	13	3.10	.03	930	38	12	87	80
C30500	0	2	W-229815	5.33	438	.050	71	21	3.04	.04	775	44	14	98	76
C40500	0	2	W-231785	5.37	407	.091	78	24	2.97	.03	843	39	14	105	76
C10600	0	2	W-228523	5.80	420	.060	57	16	3.10	.04	870	34	14	87	80
C20600	0	2	W-228535	5.60	410	.150	50	10	2.90	.03	800	32	12	83	75
C30600	0	2	W-229816	5.10	406	.050	59	19	2.86	.03	777	35	13	87	68
C40600	0	2	W-231786	5.37	412	.050	85	24	2.94	.03	887	40	18	92	71
C10700	0	2	W-228524	5.80	410	.110	54	9.5	3.10	.04	840	32	15	91	80
C20700	0	2	W-228536	5.90	430	.055	54	20	3.00	.03	760	34	12	100	80
C30700	0	2	W-229817	5.48	443	.063	67	22	3.10	.03	710	39	11	98	76
C40700	0	2	W-231787	5.40	411	.055	78	21	2.95	.03	599	34	14	92	73
C10800	0	2	W-228525	5.90	430	.075	52	20	3.10	.03	570	31	14	75	80
C20800	0	2	W-228537	6.10	430	.083	58	21	3.10	.03	610	38	12	110	81
C30800	0	2	W-229818	5.63	441	.058	69	22	3.18	.03	510	45	14	102	80
C10900	0	2	W-228526	6.10	440	.220	58	17	3.30	.03	850	34	15	100	85
C20900	0	2	W-228538	6.30	440	.091	58	22	3.30	.03	800	37	13	100	81
C30900	0	2	W-229819	5.64	451	.066	69	23	3.25	.02	723	47	13	106	80
C40900	0	2	W-231788	5.72	429	.063	83	24	3.16	.03	587	45	12	110	85
C11000	0	2	W-228527	5.20	360	.050	46	16	2.70	.02	510	25	11	79	68
C21000	0	2	W-228539	5.00	350	.055	44	16	2.60	.03	520	24	7.5	87	65
C31000	0	2	W-229820	4.64	363	.033	55	15	2.61	.02	554	30	10	84	61
C41000	0	2	W-231789	4.75	345	.033	70	17	2.60	.03	594	36	9.1	82	68
C11100	0	2	W-228528	6.30	420	.066	59	25	3.30	.03	920	40	14	110	85
C21100	0	2	W-228540	6.10	410	.075	56	20	3.20	.03	660	32	14	96	83
C31100	0	2	W-229821	5.35	409	.058	64	20	3.05	.03	669	43	13	84	75
C41100	0	2	W-231790	5.52	392	.033	79	21	3.08	.03	699	43	14	94	83
C11200	0	2	W-228529	3.50	260	.140	28	10	1.90	.02	660	16	7.0	50	46
C21200	0	2	W-228541	3.80	270	.220	32	10	2.00	.02	660	19	5.8	69	50
C31200	0	2	W-229822	3.21	258	.050	39	11	1.82	.02	590	19	6.3	54	43
C41200	0	2	W-231791	3.20	246	.028	46	11	1.73	.02	626	17	6.3	45	43
C11300	0	2	W-228627	5.80	420	.100	60	24	3.20	.03	590	48	22	80	76
C21300	0	2	W-228542	6.30	430	.070	60	23	3.40	.04	790	36	16	116	90
C31300	0	2	W-229823	5.12	404	.058	64	20	2.94	.04	695	44	16	87	78
C41300	0	2	W-231792	5.70	407	.075	81	28	3.21	.04	776	46	23	98	88
C41400	0	2	W-231793	5.57	393	.055	78	22	3.08	.04	764	40	22	96	88

According to some preliminary microscopic analyses of the sand fraction by Mr. Brian Dade, WHOI, the very high (50 percent) sand fraction at Station 12 is composed primarily of foraminifera tests. Because the metal concentration of calcite making up the foram tests is much lower than concentrations found in the clay minerals, the sand fraction in these samples essentially dilutes the metal concentrations with little influence on their relative proportions. Similar covariation in metals, organic carbon, and clay content was observed among the stations of the Georges Bank Monitoring Program (Bothner and others, 1982). On Georges Bank, however, the sand fraction was composed primarily of quartz and feldspar.

Changes in metal concentration as a result of drilling

At Station 1, drilling began just after Cruise 1 and was completed before Cruise 2. One bulk (undifferentiated with respect to size) sample was analyzed from each of three box cores collected on each of the four cruises. Two additional replicates were analyzed from one box core on each of the first three cruises (total of 5 replicates) (Table 4A and B). There is no statistically significant difference in the mean concentrations of Ba among the four cruises. However, in one replicate from Cruise 3, we measured 493 ppm Ba, which is significantly higher than the predrilling mean value of 422 ± 15 ppm. The Ba profile with depth in this core (see next section) confirms that the surface material is enriched.

There are two other indicators of a small enrichment of Ba in the surface sediment at Station 1 in the postdrilling samples. The first is the Ba to Al ratio ($[Ba, ppm/Al, \%] \cdot 10^4$) which normalizes the Ba data for inhomogeneity in clay and/or salt content of the sediment. There is an increase in the Ba to Al ratio from 77.85 ± 0.55 on Cruise 1 to 82.28 ± 3.37 on Cruise 2. The difference is statistically significant at the 95 percent level of confidence

(t test) and represents an increase of 5.7 percent. The average Ba to Al ratio for Cruises 3 and 4 are also higher than that for Cruise 1, but the differences are not statistically significant.

The third indicator is the Ba concentration and Ba to Al ratio within the sediment fraction finer than 60 micrometers, which are as much as 7 percent and 15 percent higher, respectively, in postdrilling samples than in predrilling samples (Station 1, Table 6). Individual replicate box core samples of the fine fraction should be analyzed to determine the statistical significance of this apparent difference.

Station 13, 1.3 km southwest of the drill site in Block 93 and Station 14 right at the drill site, show no evidence of increased Ba or Ba to Al ratio as a result of drilling.

Preliminary analysis of trends in the other metals over the first four cruises revealed no differences that could be attributable to drilling. There is some noise in the data, which is due in part to within-station variability and in part to instrument variability. The variability in Cr, for example, is attributed to small changes in instrument sensitivity, which can be evaluated using the results on replicate sediment standards analyzed with each batch of samples.

Trace-metal variations with depth in sediments

Samples from four stations have been subsampled as a function of sediment depth to determine the depth profiles of metal concentrations. The metal concentrations are shown in Table 7.

In the core collected at Station 1 before drilling began, the concentration of Ba and the Ba to Al ratio were essentially constant for the entire length of the core (Fig. 3). In the core collected during Cruises 2 and 3, the Ba concentration and the Ba to Al ratio were higher in surface

Table 6. - Chemical analyses of the fine fraction (less than 60 μ m) from station blends.

Field no.	Top (cm)	Btm (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C10100X	0	2	W-228543	6.10	430	0.091	58	24	3.20	0.04	780	36	14	120	85
C20100X	0	2	W-228547	6.10	460	.190	58	14	3.20	.03	670	32	13	120	80
C30100X	0	2	W-229824	5.47	445	.045	67	21	3.08	.03	532	47	12	87	78
C40100X	0	2	W-231777	5.56	440	.050	81	23	3.08	.03	773	37	13	105	85
C10200X	0	2	W-228544	6.30	430	.050	58	21	3.30	.04	610	32	15	120	81
C20200X	0	2	W-228548	6.10	420	.060	58	22	3.10	.03	600	36	14	100	75
C30200X	0	2	W-229825	5.43	417	.048	70	22	3.06	.03	698	47	12	96	76
C10300X	0	2	W-228545	5.90	410	.083	56	16	3.10	.03	590	30	15	110	76
C20300X	0	2	W-228549	5.90	420	.180	56	22	3.00	.03	500	32	11	100	76
C10400X	0	2	W-228546	5.80	400	.046	56	19	2.90	.04	560	32	14	100	73
C20400X	0	2	W-228550	5.80	390	.066	54	22	3.00	.03	810	31	15	100	73
C30400X	0	2	W-229826	5.22	402	.045	68	22	2.87	.02	702	47	12	96	70
C40400X	0	2	W-231778	5.43	420	.055	81	27	2.97	.04	662	39	12	101	76
C11300X	0	2	W-228628	6.00	430	.083	64	26	3.30	.03	590	49	22	90	76
C21300X	0	2	W-228551	6.30	420	.078	61	23	3.30	.06	690	38	21	120	90
C31300X	0	2	W-229827	5.74	434	.066	72	23	3.33	.04	743	54	17	94	86
C41300X	0	2	W-231779	5.79	415	.073	85	25	3.28	.06	781	46	22	110	90
C41400X	0	2	W-231780	5.70	398.	.063	81	22	3.17	.04	776	42	22	110	78

Table 7. - Chemical analyses of core samples subsectioned in 2-cm intervals.

Field no.	Top (cm)	Btm (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C10111	0	2	W-228480	5.00	410	0.030	48	16	2.90	0.06	830	39	15	90	76
C10111	2	4	W-228481	5.00	410	.048	51	12	2.90	.04	960	40	13	90	75
C10111	4	6	W-228482	5.00	410	.048	48	13	2.90	.04	950	39	15	83	73
C10111	8	10	W-228483	5.00	410	.055	50	21	2.80	.02	490	39	14	89	76
C10111	12	14	W-228484	5.00	410	.083	52	17	2.80	.03	410	39	12	87	76
C10111	16	18	W-228485	5.00	410	.091	51	12	2.80	.03	320	36	12	100	75
C10111	22	24	W-228486	5.00	410	.080	49	15	2.70	.03	320	39	11	90	70
C10111	28	30	W-228487	4.90	400	.110	49	14	2.70	.03	320	40	12	87	73
C20131	0	2	W-228488	4.90	430	.075	56	15	2.90	.03	680	40	16	85	81
C20131	2	4	W-228489	5.00	400	.055	52	18	3.00	.04	660	41	14	85	76
C20131	4	6	W-228490	4.90	410	.048	48	14	2.90	.03	450	40	15	90	70
C20131	8	10	W-228491	4.90	400	.066	50	15	2.80	.03	340	40	13	87	75
C20131	12	14	W-228492	5.10	420	.063	51	22	2.90	.03	350	40	12	87	73
C20131	16	18	W-228493	5.10	400	.075	53	29	2.90	.02	330	44	11	85	73
C20131	22	24	W-228494	5.00	390	.063	53	17	2.90	.03	330	44	11	93	75
C20131	28	30	W-228495	5.10	390	.083	52	23	2.90	.02	330	42	11	89	75
C30111	0	2	W-229828	5.08	493	.041	62	22	2.87	.03	565	41	12	90	73
C30111	2	4	W-229790	5.62	509	.057	60	23	3.12	.02	542	40	9.8	102	89
C30111	4	6	W-229791	5.47	441	.066	63	21	2.90	.02	317	48	7.3	95	87
C30111	8	10	W-229792	5.64	451	.065	65	22	3.16	.02	341	50	8.7	102	90
C30111	12	14	W-229793	5.70	450	.065	61	23	3.25	.04	353	46	9.4	100	89
C30111	16	18	W-229794	5.77	453	.066	63	23	3.05	.02	354	46	7.3	98	89
C30111	22	24	W-229795	5.78	445	.075	61	24	3.13	.02	357	42	7.9	95	90
C30111	24	26	W-229796	5.66	449	.077	61	30	3.17	.02	360	44	7.9	95	90
C40121	0	2	W-232023	5.08	404	.037	79	19	2.81	.04	819	36	9.1	87	61
C40121	2	4	W-232024	5.37	412	.050	80	20	2.98	.04	603	36	10	94	61
C40121	4	6	W-232025	5.39	423	.050	80	22	2.98	.04	391	36	10	104	65
C40121	6	8	W-232026	5.38	423	.058	80	22	2.94	.04	355	39	7.5	100	70
C40121	8	10	W-232027	5.33	423	.240	81	23	2.92	.04	355	39	7.5	90	70
C40121	14	16	W-232028	5.54	415	.071	84	23	2.99	.04	346	36	9.6	102	75
C40121	20	22	W-232029	5.43	419	.075	80	23	3.00	.04	359	37	9.8	107	75
C40121	24	26	W-232030	5.45	414	.055	83	22	3.00	.04	362	36	9.1	102	61
C10611	0	2	W-228496	5.10	430	.090	52	19	2.80	.03	740	45	17	75	78
C10611	2	4	W-228497	5.30	440	.075	54	17	3.00	.03	680	51	14	90	81
C10611	4	6	W-228498	5.30	450	.120	56	18	2.90	.02	370	47	13	97	80
C10611	8	10	W-228499	5.30	440	.130	53	27	2.80	.03	330	47	14	87	80
C10611	12	14	W-228500	5.30	450	.075	53	16	2.90	.03	330	47	14	90	80
C10611	16	18	W-228501	5.30	460	.110	56	15	2.90	.01	340	51	13	91	80
C10611	22	24	W-228502	5.20	420	.110	55	17	2.90	.04	340	49	11	100	81
C20611	0	2	W-228503	4.80	420	.063	51	17	2.70	.03	880	45	15	100	71
C20611	2	4	W-228504	5.00	410	.120	51	16	2.80	.03	820	45	14	89	75
C20611	4	6	W-228505	5.10	420	.075	52	17	2.70	.03	350	42	13	100	80
C20611	8	10	W-228506	5.30	410	.091	52	18	2.90	.03	330	48	13	85	76
C20611	12	14	W-228507	5.20	400	.190	52	21	2.90	.03	330	48	15	100	80
C20611	16	18	W-228508	5.20	410	.091	51	21	2.90	.02	330	44	13	100	80
C20611	20	22	W-228509	5.20	420	.100	54	20	3.00	.06	340	47	13	100	80
C30631	0	2	W-229835	5.24	409	.045	69	22	3.01	.02	1,202	47	13	94	73
C30631	2	4	W-229797	5.76	458	.054	63	25	3.24	.02	801	48	12	102	90
C30631	4	6	W-229798	5.64	455	.077	61	24	3.09	.02	409	42	11	98	90
C30631	8	10	W-229799	5.49	456	.100	59	24	3.02	.02	331	46	13	98	87
C30631	12	14	W-229800	5.62	445	.100	57	24	3.11	.02	338	42	13	98	85
C30631	16	18	W-229801	5.74	457	.110	61	24	3.23	.02	341	46	10	102	87
C30631	20	22	W-229802	5.74	457	.066	60	22	3.22	.02	341	43	7.7	110	87
C30631	24	26	W-229803	5.83	457	.066	66	24	3.27	.02	346	50	7.3	98	90

Table 7. - Chemical analyses of core samples subsectioned in 2-cm intervals-Continued.

Field no.	Top (cm)	Btm (cm)	Lab no.	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
C40600	0	2	W-231786	5.37	412	0.050	85	24	2.94	0.03	887	40	18	92	71
C40611	2	4	W-232031	5.60	429	.045	84	23	3.15	.04	1187	40	11	104	70
C40611	4	6	W-232032	5.57	435	.055	84	23	3.12	.04	637	40	10	104	68
C40611	6	8	W-232033	5.58	446	.091	84	24	3.04	.04	357	40	11	120	68
C40611	8	10	W-232034	5.63	446	.083	83	25	3.06	.04	345	39	11	104	75
C40611	10	12	W-232035	5.58	446	.063	82	26	3.00	.04	340	39	10	120	75
C40611	16	18	W-232036	5.52	431	.083	84	28	2.98	.04	345	39	8.8	110	61
C40611	22	24	W-232037	5.52	438	.110	82	23	3.06	.04	356	42	9.1	102	76
C40611	28	30	W-232038	5.56	432	.083	83	22	3.08	.04	358	42	9.1	120	70
C11311	0	2	W-228600	6.00	430	.110	60	28	3.40	.04	800	45	27	86	81
C11311	2	4	W-228601	6.00	430	.100	62	30	3.40	.03	700	45	19	84	81
C11311	4	6	W-228602	6.10	440	.083	64	29	3.40	.02	350	45	17	100	76
C11311	8	10	W-228603	6.20	460	.230	63	28	3.20	.02	320	47	12	110	80
C11311	12	14	W-228604	6.10	440	.180	62	25	3.10	.02	320	47	15	86	78
C11311	16	18	W-228605	6.10	440	.180	62	29	3.20	.02	330	44	13	92	76
C11311	24	26	W-228606	6.20	440	.200	66	24	3.30	.02	320	50	9.1	100	76
C21311	0	2	W-228593	6.00	430	.096	58	29	3.40	.06	880	48	24	84	80
C21311	2	4	W-228594	6.10	440	.075	58	25	3.50	.03	440	45	16	80	76
C21311	4	6	W-228595	6.20	450	.160	62	28	3.40	.03	340	47	14	86	78
C21311	8	10	W-228596	6.00	430	.190	68	25	3.20	.02	310	47	13	84	75
C21311	12	14	W-228597	6.20	440	.170	60	28	3.30	.02	320	47	11	84	78
C21311	16	18	W-228598	6.10	430	.200	60	25	3.30	.02	330	47	13	89	75
C21311	24	26	W-228599	5.90	420	.220	60	26	3.30	.02	330	47	11	90	76
C31311	0	2	W-229836	5.45	425	.066	69	24	3.10	.03	611	50	25	104	80
C31311	2	4	W-229804	5.96	461	.058	71	25	3.43	.03	723	50	18	107	100
C31311	4	6	W-229805	5.99	454	.050	66	25	3.44	.03	707	46	17	107	100
C31311	8	10	W-229806	6.05	453	.100	60	24	3.36	.03	351	42	14	115	98
C31311	12	14	W-229807	6.33	471	.130	65	24	3.46	.02	319	44	9.1	110	99
C31311	16	18	W-229808	6.23	467	.120	65	24	3.37	.02	301	42	7.7	107	98
C31311	24	26	W-229809	6.17	465	.130	68	23	3.43	.02	319	47	7.3	110	98
C31311	28	30	W-229810	6.00	453	.130	68	23	3.29	.02	312	48	9.1	107	95
C41331	0	2	W-231769	5.63	412	.066	81	26	3.15	.03	783	40	20	92	100
C41331	2	4	W-231751	5.90	442	.066	78	25	3.28	.05	417	43	25	112	90
C41331	4	6	W-213752	6.00	437	.140	79	27	3.29	.04	355	45	22	124	91
C41331	6	8	W-231753	6.04	450	.120	81	26	3.23	.03	343	43	15	130	88
C41331	8	10	W-231754	6.07	444	.150	79	26	3.26	.02	343	43	11	121	88
C41331	10	12	W-231755	6.01	445	.160	78	23	3.22	.02	336	46	9.6	130	83
C41331	16	18	W-231756	5.93	434	.140	77	24	3.24	.02	341	40	9.6	121	85
C41331	22	24	W-231757	5.91	434	.120	77	24	3.26	.02	345	45	9.6	126	83
C41331	26	28	W-231758	5.96	476	.160	78	24	3.27	.01	363	45	9.6	130	85
C11411	0	2	W-230725	5.91	406	.061	76	23	3.31	.04	766	42	23	97	83
C11411	2	4	W-230726	5.94	397	.055	75	22	3.34	.02	565	39	16	106	83
C11411	4	6	W-230727	6.00	410	.100	74	24	3.20	.02	334	40	15	106	85
C11411	6	8	W-230728	6.03	417	.140	78	23	3.16	.02	328	40	13	101	83
C11411	12	14	W-230729	5.84	400	.120	68	22	3.09	.01	319	40	11	93	80
C11411	18	20	W-230730	5.84	405	.100	73	22	3.21	.01	327	42	12	106	78
C11411	24	26	W-230731	5.86	408	.100	75	19	3.24	.01	324	40	8.3	101	78
C11411	28	30	W-230732	5.87	408	.120	73	21	3.24	<.01	335	42	7.8	101	81
C11411	32	34	W-230733	5.97	411	.180	76	23	3.32	.01	338	42	11	106	81
C41421	0	2	W-231772	5.60	389	.071	81	21	3.10	.04	689	36	20	87	86
C41421	2	4	W-231759	5.93	428	.083	77	25	3.21	.02	386	40	15	124	83
C41421	4	6	W-231760	6.00	443	.150	78	24	3.20	.02	350	40	13	126	83
C41421	6	8	W-231761	6.00	438	.140	78	23	3.18	.02	345	42	11	130	83
C41421	8	10	W-231762	5.95	444	.150	78	28	3.14	.02	346	42	10	130	85
C41421	10	12	W-231763	5.96	457	.150	77	30	3.14	.03	344	42	12	126	83
C41421	16	18	W-231764	6.00	446	.150	78	25	3.18	.02	345	42	9.7	125	83
C41421	22	23	W-231765	6.07	450	.190	76	23	3.23	.01	339	40	8.1	124	83

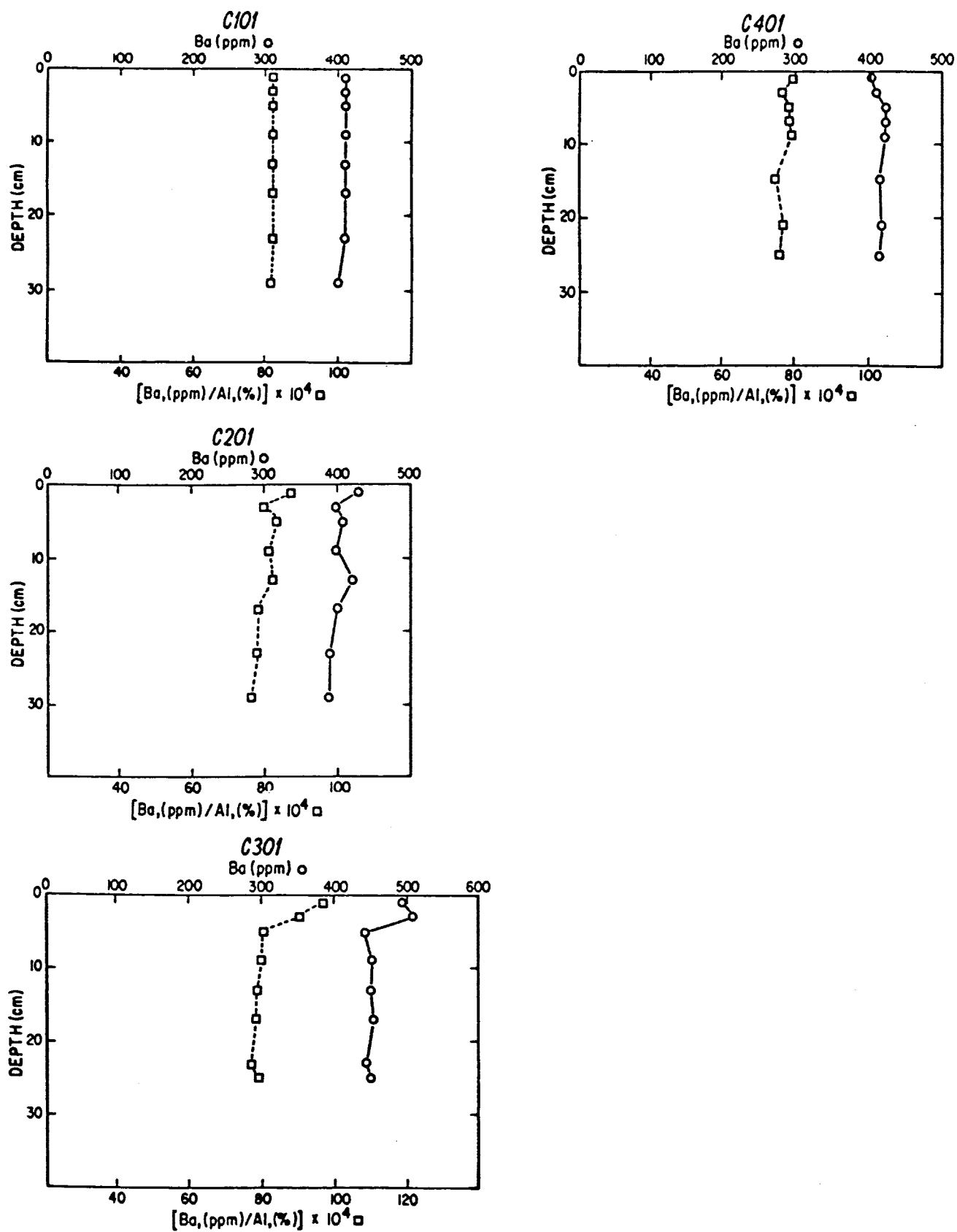


Figure 3. Distribution of barium and barium to aluminum ratio with sediment depth; Cruises 1-4, Station 1. (C101 = Cruise 1, Station 1)

sediments than in subsurface sediments. In postdrilling cores, the Ba maximum concentration and Ba to Al ratio within 4 cm of the sediment surface were 13 and 25 percent higher, respectively, than in samples deeper in the sediment. These trends support the preliminary conclusion that a small increase in drilling-related Ba can be measured at Station 1.

At Station 6, the distribution of Ba and the Ba to Al ratio were more variable with depth than observed at Station 1 (Fig. 4). There were small increases in both values at the surface of the core from Cruise 2 compared to that from Cruise 1, but no indications of enhanced Ba deposition in samples from Cruises 3 and 4. Station 6 is located about 83 km from the drilling in Block 372.

At Station 13, samples showed essentially no differences in the concentration of Ba or in the Ba to Al ratio among Cruises 1 through 4 (Fig. 5). This station is located about 1.3 km southwest of the drilling site in Block 93. Drilling began on July 14, 1984 about four weeks before Cruise 2 and was completed November 4, 1984 just before Cruise 3.

Samples from Station 14 (drill site in Block 93) were collected only on Cruises 1 and 4 (Fig. 6). The profiles of Ba and Ba to Al ratio are essentially the same for both the predrilling and postdrilling samples.

In cores collected on Cruise 1 at Stations 1, 6, 13, and 14, the concentration of Ba and the Ba to Al ratio in the surface sediments were not elevated in comparison with deeper sediments. This suggests that the drilling which occurred before Cruise 1 did not contribute Ba to the general area of this survey to a measurable degree.

The concentrations of Mn and Pb in the upper few centimeters of these cores were consistently higher than in the deeper sediments (Figs. 7-12). The profiles of these metals for all four cruises at a given station are very

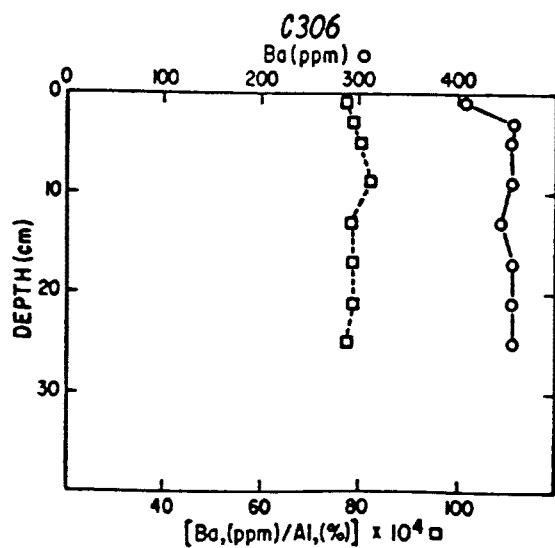
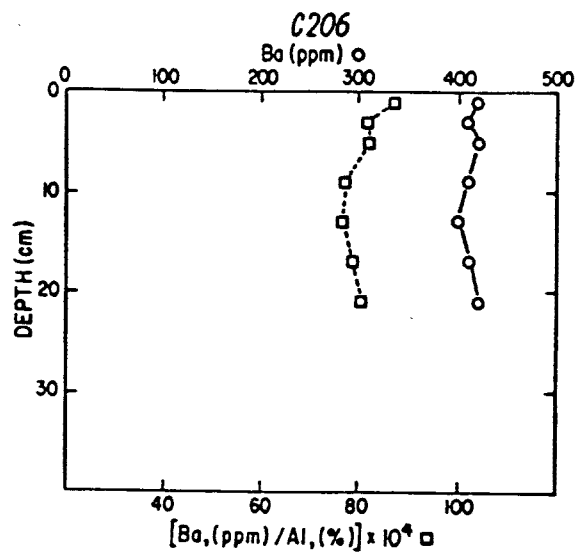
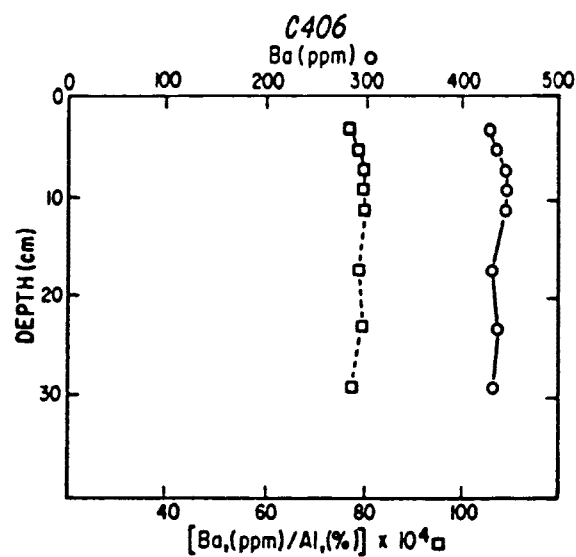
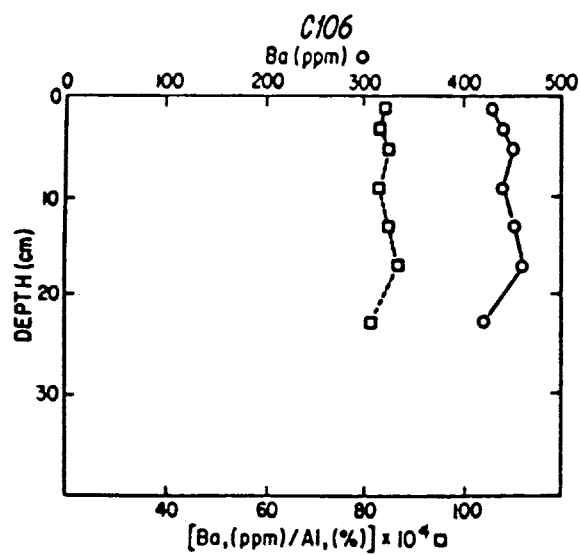


Figure 4. Distribution of barium and barium to aluminum ratio with sediment depth: Cruises 1-4, Station 6.
(C106 = Cruise 1, Station 6).

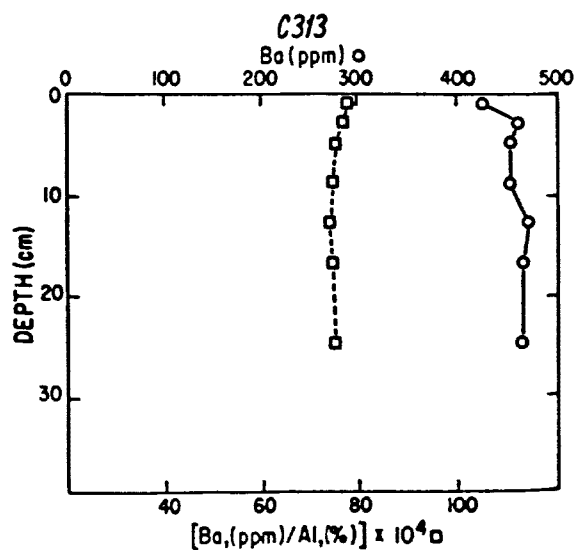
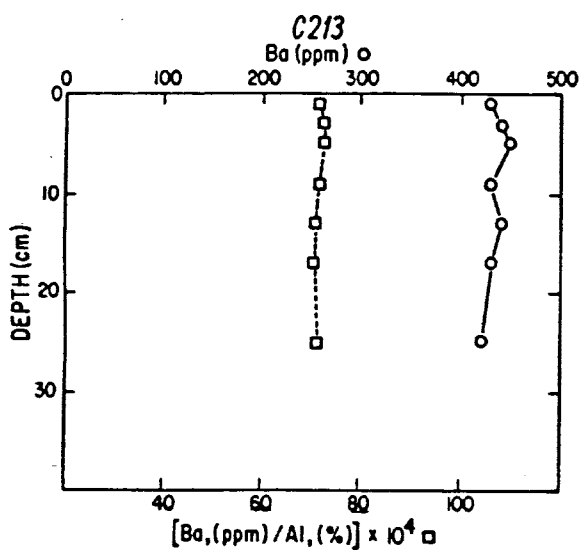
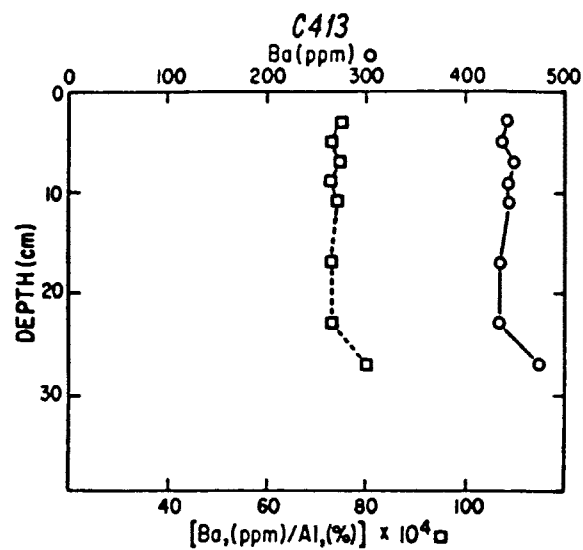
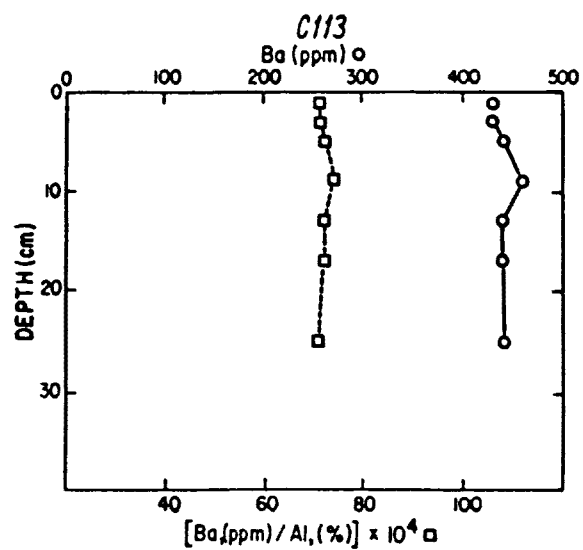


Figure 5. Distribution of barium and barium to aluminum ratio with sediment depth: Cruises 1-4, Station 13.
(C113 = Cruise 1, Station 13)

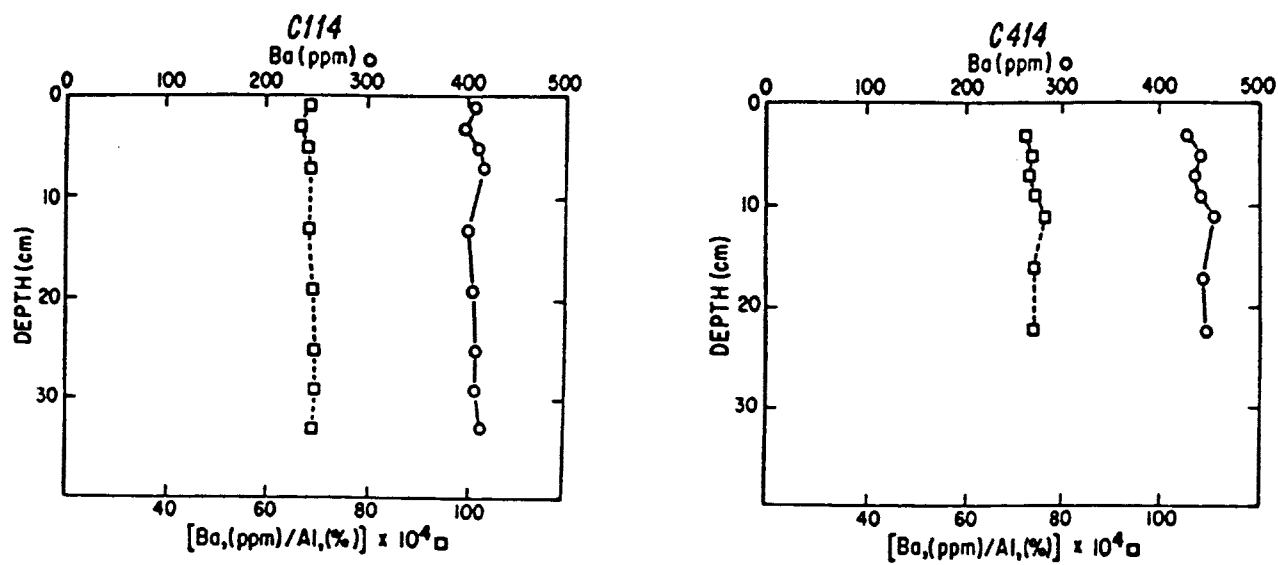


Figure 6. Distribution of barium and barium to aluminum ratio with sediment depth; Cruises 1 and 4, Station 14. (C101 = Cruise 1, Station 1)

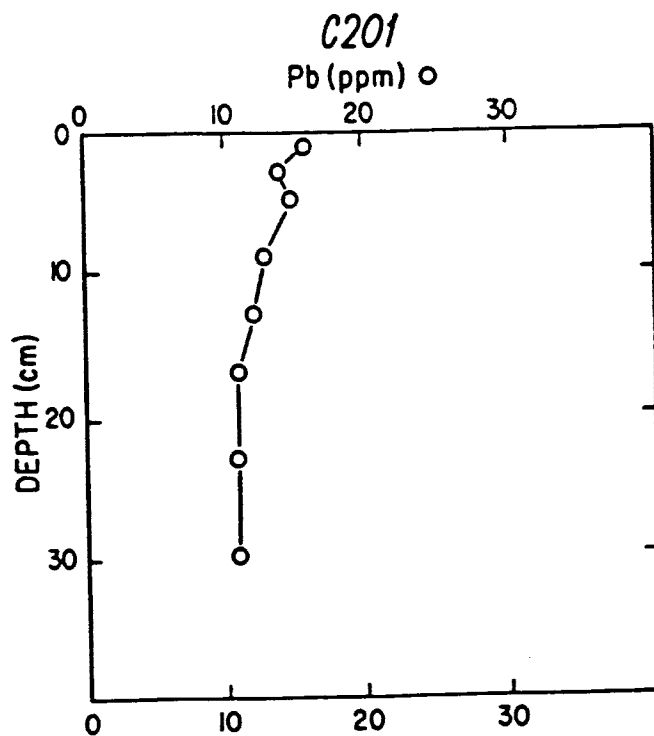
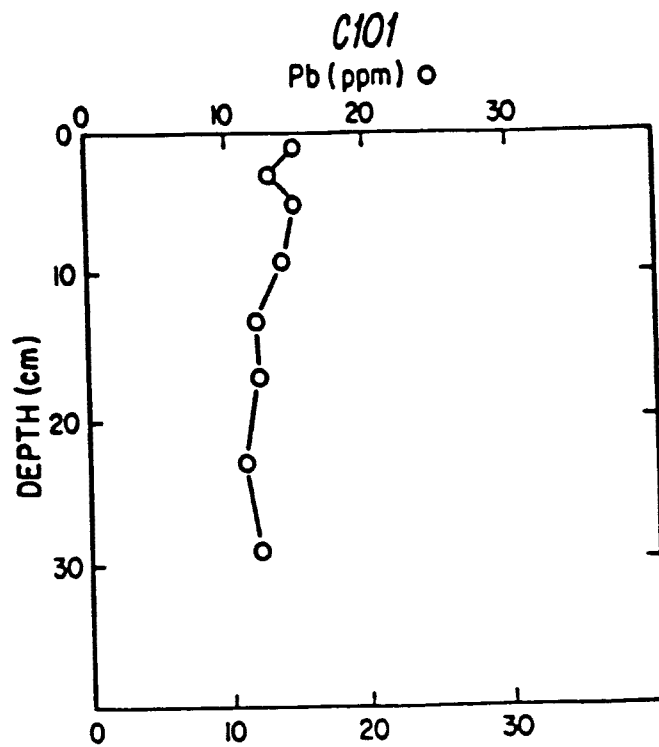


Figure 7. Distribution of lead with sediment depth; Cruises 1 and 2, Station 1. (C101 = Cruise 1, Station 1)

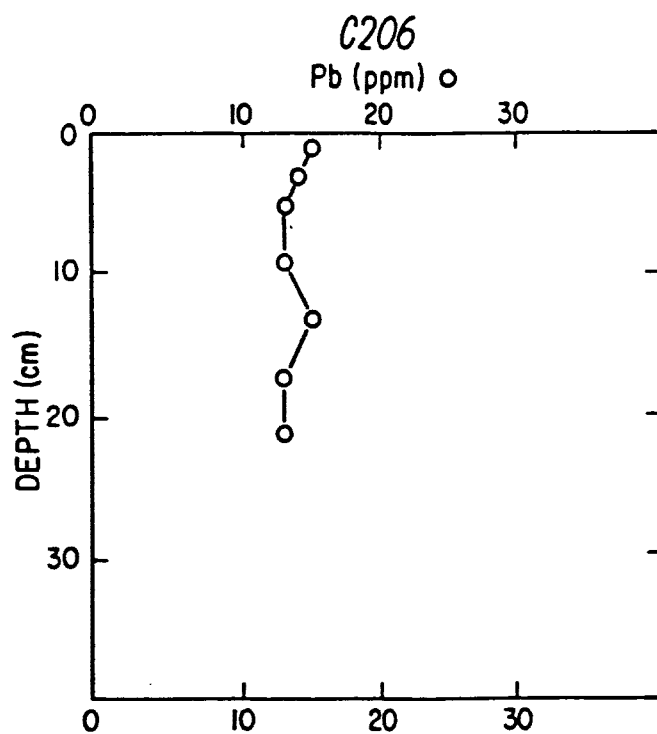
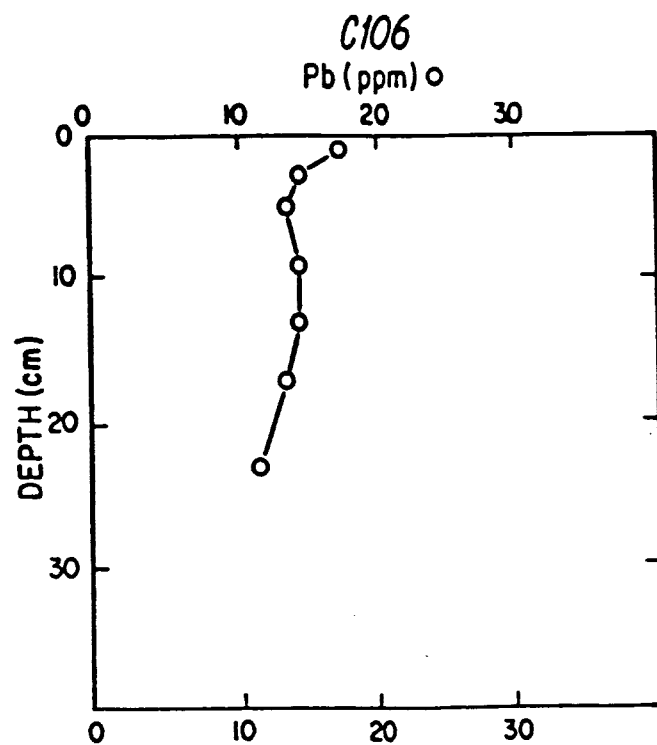


Figure 8. Distribution of lead with sediment depth;
Cruises 1 and 2, Station 6. (C106 = Cruise 1,
Station 6)

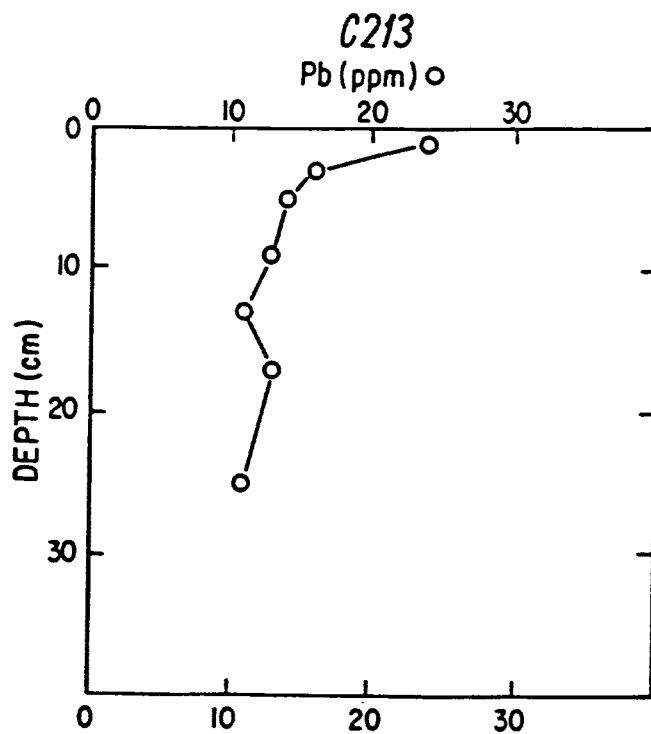
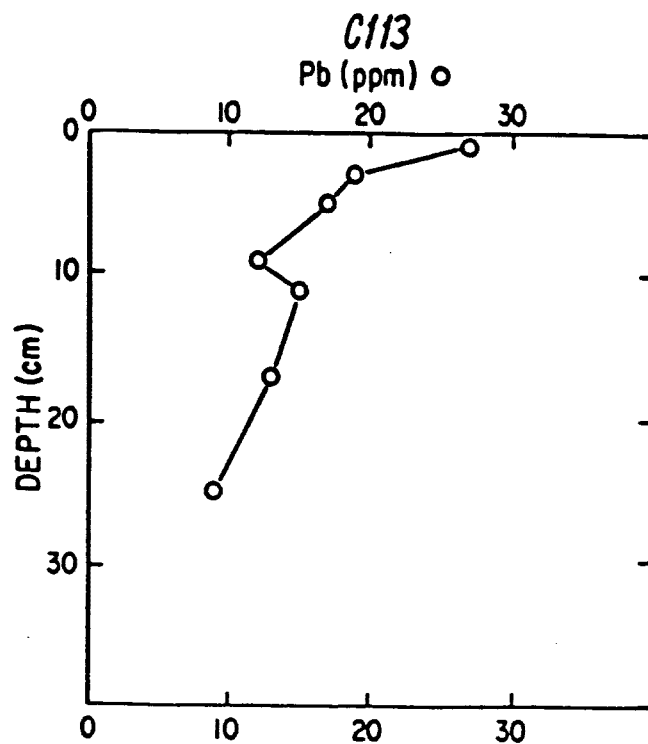


Figure 9. Distribution of lead with sediment depth; Cruises 1 and 2, Station 13. (C113 = Cruise 1, Station 13)

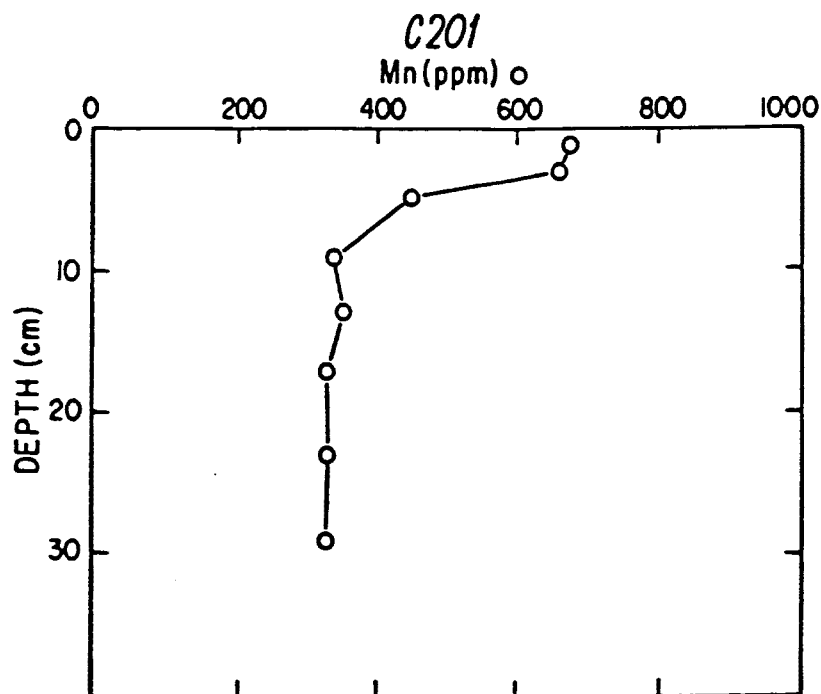
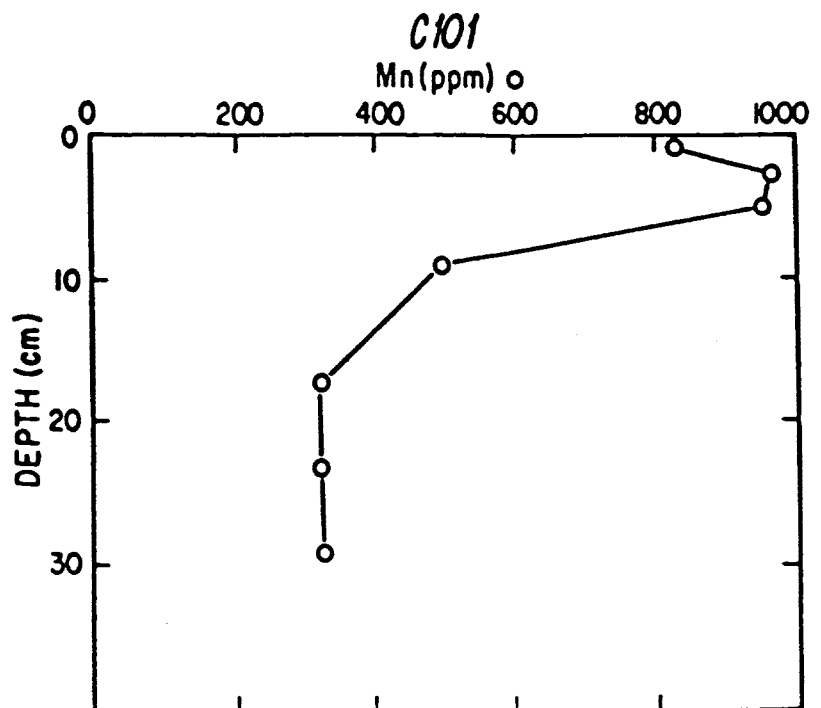


Figure 10. Distribution of manganese with sediment depth; Cruises 1 and 2, Station 1. (C101 = Cruise 1, Station 1)

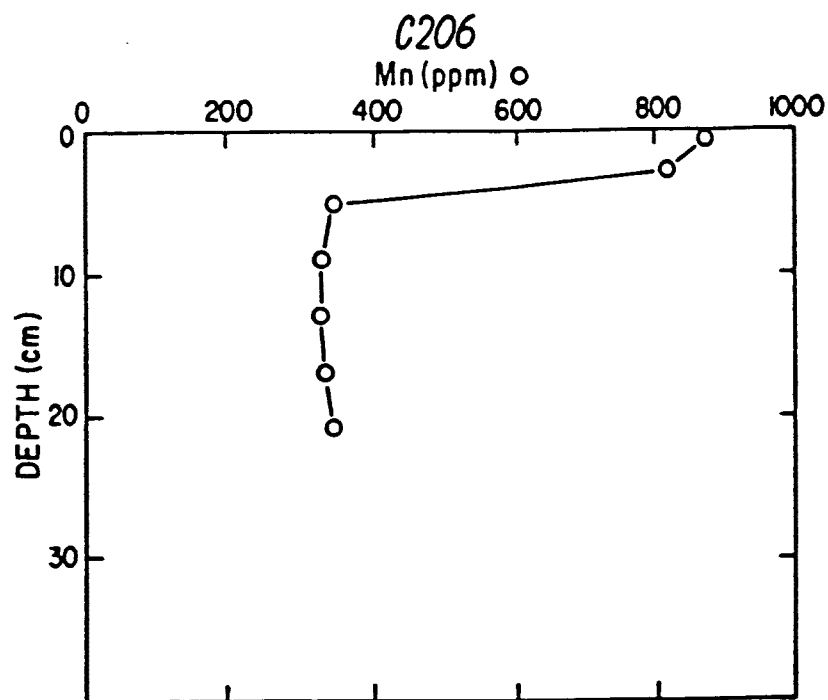
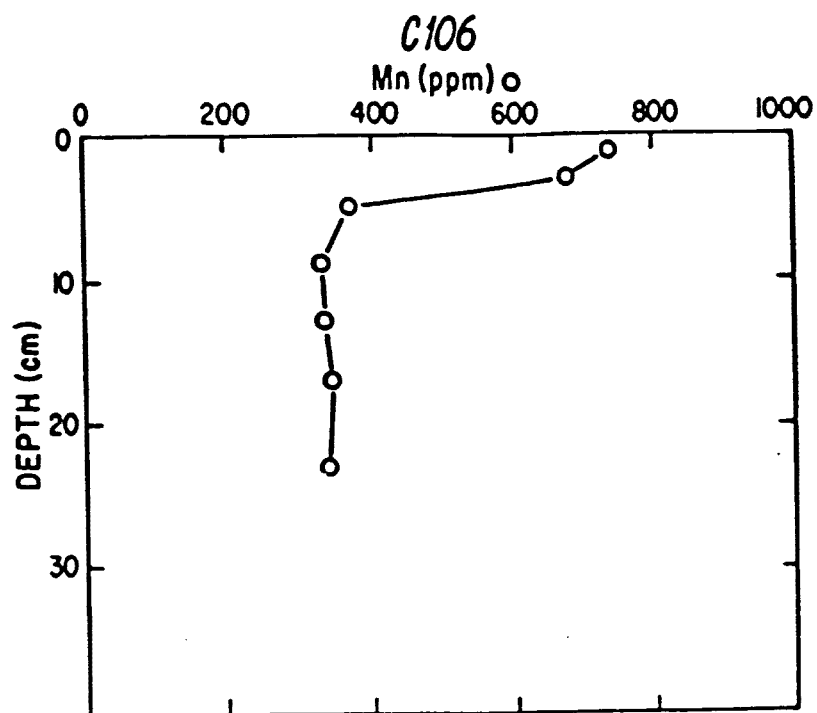


Figure 11. Distribution of manganese with sediment depth; Cruises 1 and 2, Station 6. (C106 = Cruise 1, Station 6)

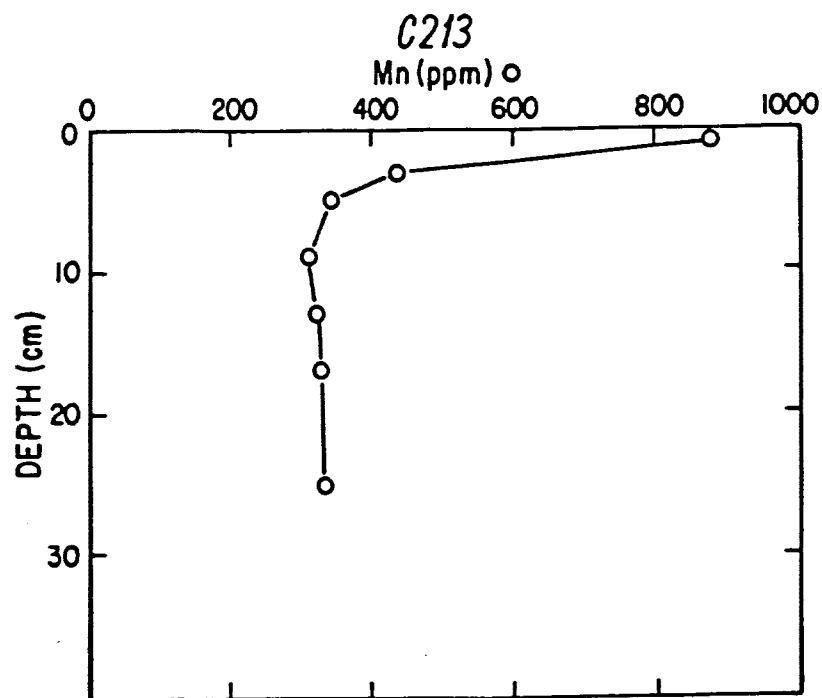
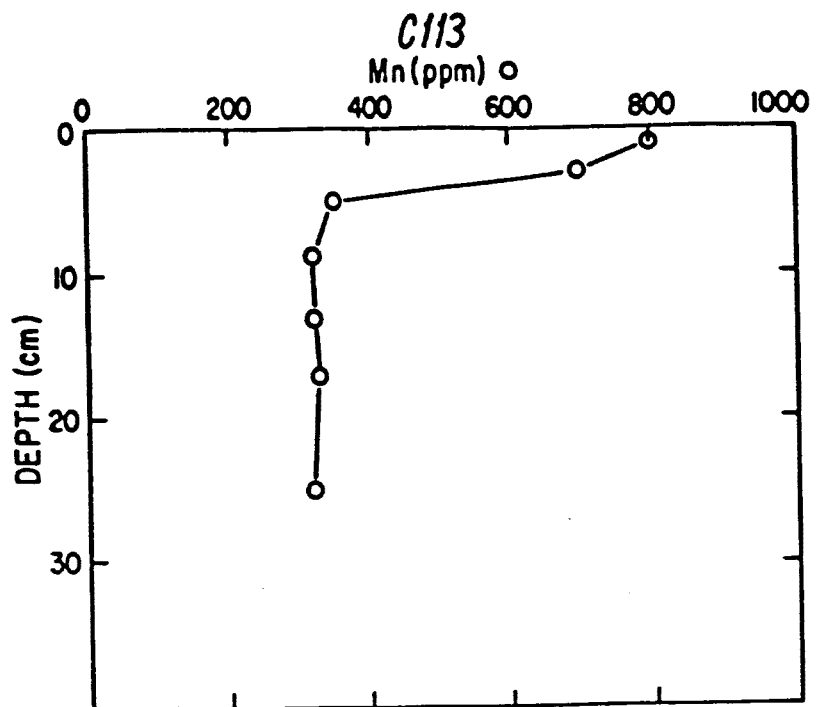


Figure 12. Distribution of manganese with sediment depth; Cruises 1 and 2, Station 13. (C113 = Cruise 1, Station 13)

similar (plots for first two cruises included), confirming that the changes with depth are unrelated to drilling. The Mn profile is typical of sediments that undergo a transition from oxidizing conditions near the water/sediment interface to reducing conditions in deeper sediments. The profile is a result of MnO_2 dissolving under reducing conditions, diffusing upward, and precipitating in the oxidizing conditions near the surface (Lynn and Bonati, 1965).

The absence of a gradient in the Ba profile in cores that have a strong gradient in Mn (for example, Stations 1 and 13 from Cruise 1) suggests that naturally occurring Ba is not migrating in the subsurface reducing conditions, at least not at a rate sufficient to measurably change the Ba concentrations of the sediments. Any increases we measure in the surface sediment relative to deeper sediment can thus be attributed to a recent addition of the metal, presumably from drilling activity, rather than to natural diagenetic processes.

The distribution of Pb with depth (Figs. 7-9 and Table 7) is a common feature in areas of fine sediment on the continental shelf and slope (Bothner and others, 1981; Bothner and others, 1985). The surficial sediments are typically as much as 2-3 times higher than sediments 25-30 cm below the water-sediment interface. The highest concentration measured in these cores is 27 ppm, slightly higher than the value in world average shales (20 ppm, Krauskopf, 1967).

The elevation in surficial sediments is thought to be related to an increased supply of lead to these sediments, probably from the burning of lead alkyls in gasoline in coastal metropolitan areas. The use of lead alkyls began in 1924 and has increased each year since 1940 until the recent switch to unleaded gasoline. The penetration of Pb to a depth of about 10 cm is probably related to biological reworking of the sediment.

The impact of this increase in lead is unknown. Important questions are: How is the Pb bound in the sediments? What is the bioavailability of this Pb? What is the response of organisms at different life stages to long term, low level Pb contamination? Although a few studies show a relationship between the concentration of lead in the tissue of deposit feeding organisms and the lead concentration in (acid leached) sediment (Luoma and Bryan, 1978; Tessier and others, 1984), no guidelines for "safe levels" of lead in sediments have been established. Work addressing this complex issue is presently funded by the Environmental Protection Agency.

Ba concentration in sediment trap samples

Thirteen sediment traps were deployed 1.8 km south-southwest of the Shell drilling site in Block 372 on June 21, 1984. The traps were placed at different elevations above the sea floor on a subsurface current-meter mooring set out by Scientific Applications, Inc. The traps were deployed for 99 days, which included the last 18 days of the drilling operations. The period near the end of drilling typically includes a final discharge of drilling fluid before the well is plugged and abandoned.

Preliminary analyses of sediments from ten of the traps have been completed. The Ba concentrations are highest in the sediment trap located nearest the surface and decrease with increasing trap depth throughout the upper half of the water column (Fig. 13). From the middle of the water column to the bottom there is a small increase in Ba concentration, but this apparent trend needs to be confirmed with additional analyses.

One subsample from trap 901 (220 m water depth) consisted of gray particles having relatively high density and containing at least 27,000 ppm Ba in the <1 micrometer size fraction (Table 8). This concentration is a lower limit since the acid decomposition method did not completely dissolve the

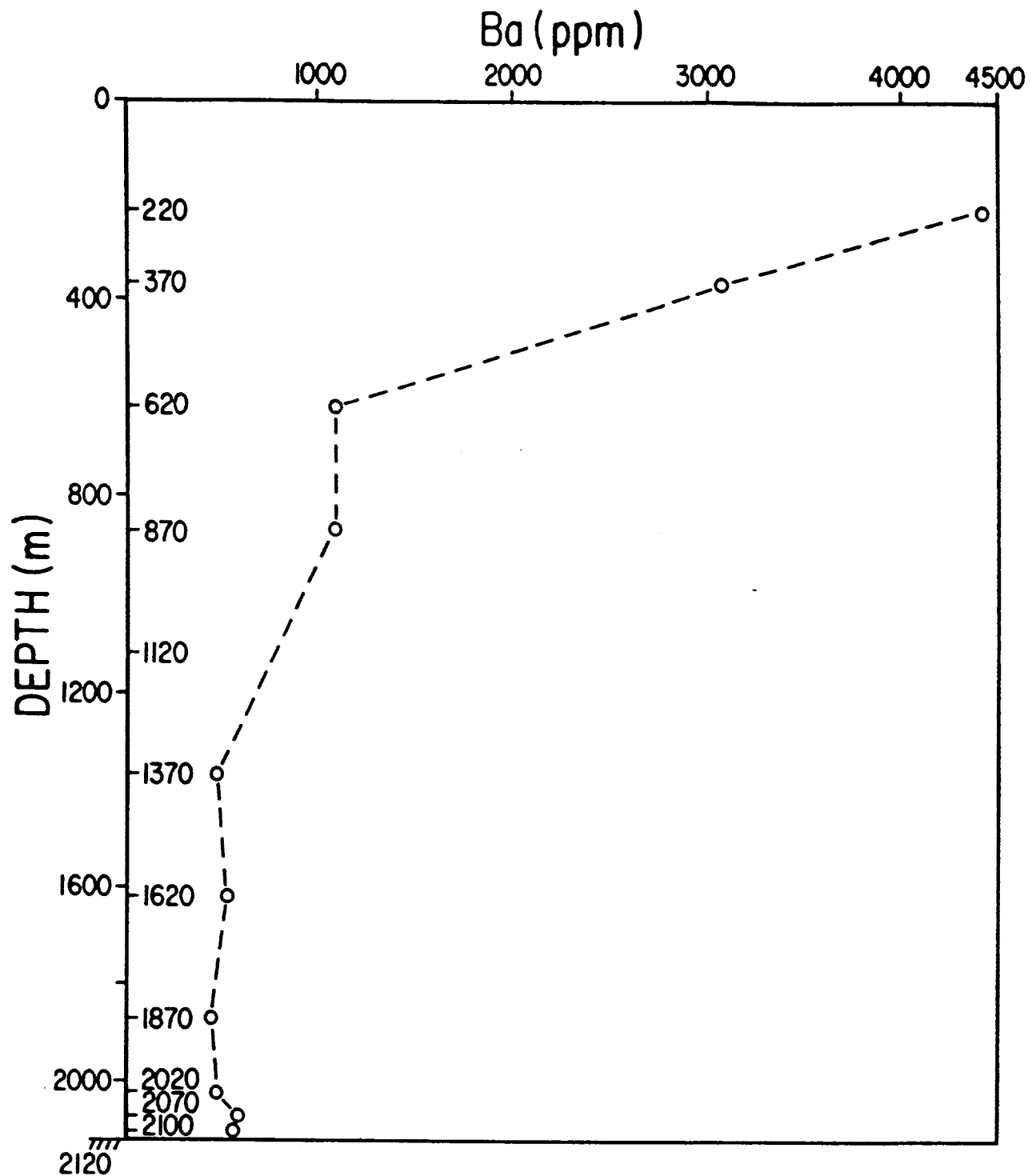


Figure 13. Average Ba concentration (ppm) in sediment trap samples (<1 mm size range) deployed at different depths near Block 93.

Table 8. Chemical analysis of sediment trap samples; mooring location: 38°35.1'N., 72°53.5'W., 2,120 m water depth.

[Missing data indicates insufficient sample size for analysis.]

Field no.	Top (cm)	Btm (cm)	Lab no.	Trap depth (m)	Al (%)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Hg (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
ST901-W	0.5	2.5	W-231615	220	0.52	29	---	28	---	3.05	---	---	31	---	11	---
ST901-W	2.5	3	W-231613	220	.02	191	---	13	---	.08	---	---	2	---	7.6	---
ST901-W	3	5	W-231614	220	.70	5,890	---	77	---	.68	---	---	42	---	23	---
ST901-Z	0.5	2	W-231620	220	1.67	896	3,790	34	30	1.14	0.09	358	14	24	20	613
ST901-Z	2.5	3	W-231619	220	.85	1,460	5,670	31	34	.50	.12	240	7.8	15	6.3	609
ST901-Z	3	5	W-231621	220	1.75	8,090	3,810	45	34	.84	.15	217	14	58	20	775
ST901-Z	5	5.3	W-231622	220	4.93	27,600	1,540	130	45	1.86	---	292	18	14	49	974
ST901-Y2	5	5.3	W-231612	220	1.94	35,800	---	47	---	1.49	---	---	45	---	28	---
ST901-Z	5.3	6	W-231611	220	5.32	11,200	1,190	140	25	2.01	---	295	48	30	32	634
ST901-P	.5	2	W-231610	220	1.62	2,770	---	110	---	.33	---	---	74	---	36	---
ST901-P	2.5	3	W-231609	220	3.59	2,300	---	307	---	.72	---	---	178	---	159	---
ST901-P	3	5	W-231607	220	1.52	4,370	---	166	---	.30	---	---	63	---	65	---
ST901-P	5	5.3	W-231608	220	7.27	21,000	---	571	---	2.08	---	---	245	---	131	---
ST903-W			W-231618	620	.03	62	---	10	---	.06	---	---	<2	---	6	---
ST903-Z			W-231599	---	3.34	1,090	---	59	---	1.71	---	---	51	---	41	---
ST904-Z			W-231600	870	3.68	1,090	---	57	---	1.85	---	---	49	---	33	---
ST906-W			W-231617	1,370	5.29	958	---	285	---	.85	---	---	348	---	162	---
ST906-Z			W-231601	---	4.07	460	---	76	---	2.20	---	---	62	---	43	---
ST907-Z			W-231602	1,620	4.62	525	<.020	66	34	2.50	---	419	43	22	52	264
ST908-W			W-231616	1,870	6.45	725	---	509	---	2.81	---	---	285	---	151	---
ST908-Z			W-231603	---	4.54	447	.071	67	43	2.48	.18	456	46	17	56	146
ST909-Z			W-231604	2,020	5.18	476	.086	74	38	2.92	---	776	53	23	90	144
ST910-Z			W-231605	2,070	5.81	586	.110	77	44	3.22	---	681	58	16	106	182
ST911-Z			W-231606	2,100	5.64	559	.120	78	34	3.13	.37	633	48	19	85	171

Field number designation: P = supernatant from centrifugation;

W = >1 mm size fraction;

Y2 = panned concentrate;

Z = <1 mm size fraction.

particles. Preliminary examination by means of the scanning electron microscope (SEM) indicated that the grey material was barium sulfate.

A recent modification of our MMS contract will allow additional SEM work on these samples. One objective of this work will be particle size analysis of the trapped barite which will be useful in estimating fall velocities of these particles.

Sediment texture

Sediment texture within the upper 30 cm of the sea floor is quite uniform (Fig. 14 and Table 9). On the basis of mean grain size, the sediments are classified as silty clays or clayey silts. The sand component varies between about 1 percent and 15 percent and is composed mostly of foraminifera and diatom tests with minor amounts of rock fragments.

The sand content at Station 1 is higher in samples taken on Cruise 2 than on Cruise 1. This difference is probably not related to the drilling. Although a few large particles, thought to be drill cuttings, were observed in other replicate surface samples from Station 1 Cruise 2 (Battelle and others, 1985), we found no unusual particles in the sand fraction of the subcores we analyzed. Natural variability at this station is a more likely explanation of the apparent difference in texture between samples collected on these two cruises.

Although small differences in the silt and clay content were observed between predrilling and postdrilling cores, the differences are generally within the 10-percent resolution of the analysis method and therefore not attributed to accumulation of drilling muds or cuttings.

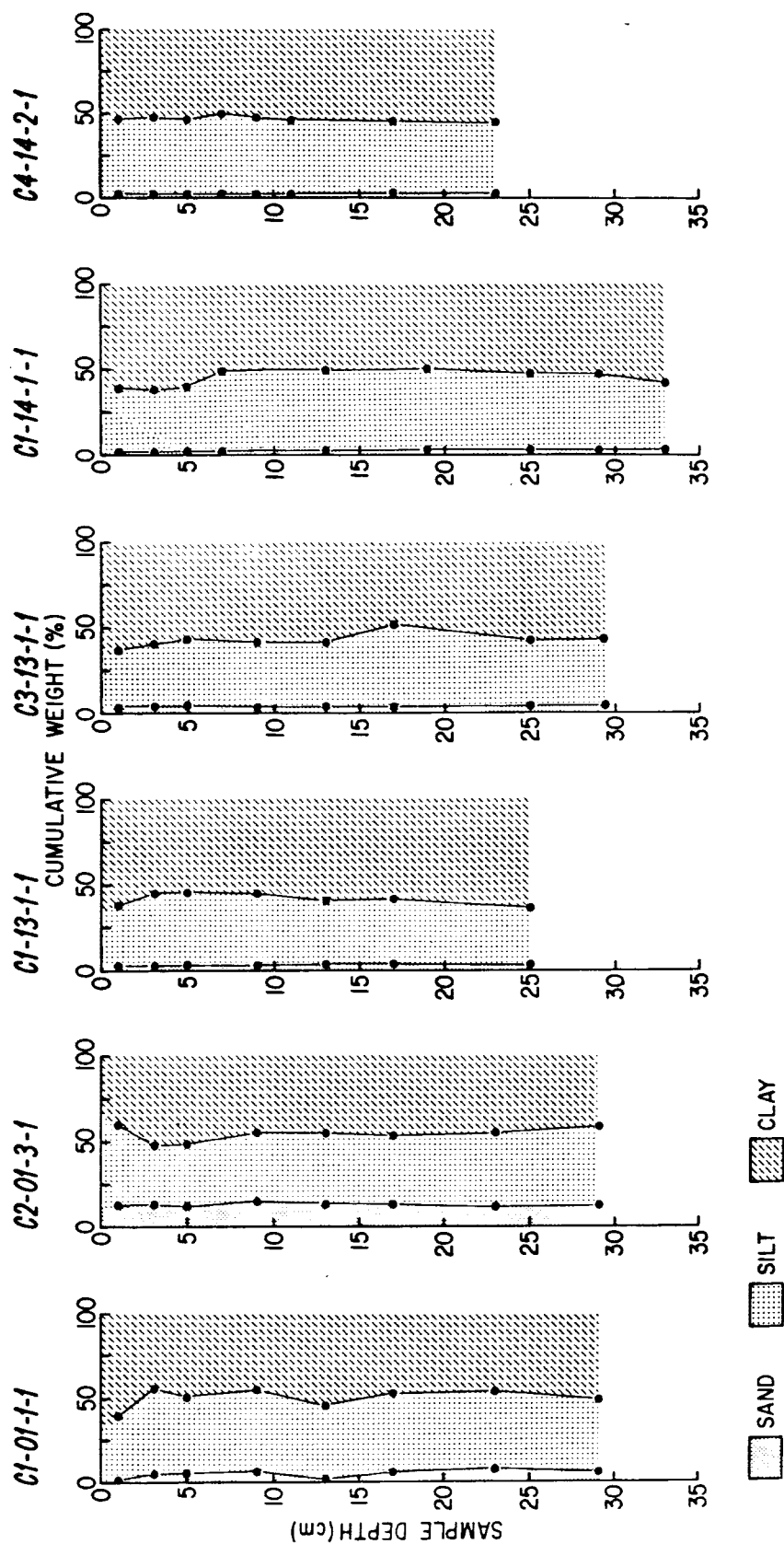


Figure 14. Grain-size analysis of sediment cores before drilling (Cruise 1) and after drilling (Cruises 2-4).

Table 9. - Textural analysis of station blends and individual samples. [Values accurate to two significant figures]

Field no.	Depth (cm)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean (%)	Median (%)	St.dev. (%)	Very coarse			Coarse			Medium			Fine			Very fine			Silt			Clay																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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SUMMARY OF IMPORTANT PRELIMINARY FINDINGS

1. At Station 1, adjacent to the drilling in Block 372, there are three lines of evidence suggesting that a small amount of drilling mud has been added to the bottom sediments. First, in one replicate core from Cruise 3, the top 4 cm of sediment had Ba concentrations as much as 13 percent higher than deeper sediments. Ba to Al ratios in the same interval were 25 percent higher. The fact that this increase was measured in only one of three subcores from the same replicate box core indicates that the elevations of Ba from drilling are patchy on a very small scale. Second, among five replicates of surface sediments, the average Ba to Al ratio was 5.7 percent higher on postdrilling Cruise 2 than on predrilling Cruise 1. This difference is statistically significant at the 95 percent level of confidence (t test). Finally, in the sediment fraction finer than 60 micrometers, the Ba to Al ratio is 15 percent higher in postdrilling than predrilling samples.

This magnitude of increase in Ba or the Ba to Al ratio is probably not deleterious to benthic marine organisms. This opinion is based on the data generated during the Georges Bank Monitoring program which showed no environmental effects to benthic organisms attributable to drilling at stations where Ba increased as much as 5.9 times background levels (Battelle-WHOI, 1985). Barium in the form of barium sulfate is also known to be of low toxicity from its wide use in the field of medicine. However, because of a lack of scientific data, there is uncertainty in predicting the response of organisms to long term, low level, contamination.

2. The strongest signal from drilling mud was observed in sediment trap samples collected within the upper 850 m of the water column at a station

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- mooring 1.8 km south-southwest of the drilling rig in Block 372. Discrete particles of barite were observed in preliminary analyses by means of a scanning electron microscope. Additional measurements of the size distribution of these particles may yield important information on the dispersion and fall velocity of barite discharged by this well.
3. There are no changes in Ba concentration at the drill site in Block 93, Stations 13 or 14. However, the full suite of samples from Station 14, added later in the program, have not yet been analyzed.
 4. In cores collected on Cruise 1 at Stations 1, 6, 13, and 14, the concentration of Ba and the Ba to Al ratio in the surface sediments were not elevated with respect to deeper sediments. This suggests that the drilling mud from exploratory wells on the slope and on the Continental Shelf, which were active before Cruise 1, either was not deposited in the general area of this survey or was diluted with natural sediments to levels below detection.
 5. Within the surface sediments sampled in this program, the analyzed metals are the same or lower in concentration than they are in average shales from around the world, an indication of uncontaminated sediments. For example, the highest concentration of Ba in sediments collected at the drill site in Block 372 after the completion of drilling was 509 ppm; less than the published value of 580 ppm for average shales.
 6. Pb concentrations are as much as three times higher in the upper 5-10 cm than they are in deeper sediments of the cores collected. Similar Pb profiles have been previously described in sediments from other locations off the U.S. east coast. The enrichment is thought to be related to the burning of gasoline containing lead additives and its subsequent atmospheric transport to offshore marine areas. Too little data is

available in the literature to evaluate the potential impact of this increase in Pb. Data is lacking on the speciation and bioavailability of lead in sediments and on the effects of small increases (compared to some estuaries) of Pb on organisms inhabiting this deep environment.

7. The analysis of sediment texture in sediment cores revealed no differences in predrilling and postdrilling samples at stations adjacent to drilling operations. This suggests that there is not a measurable amount of drill cuttings accumulating at the locations sampled.

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Appendix Table 1. - Navigation data for samples analyzed for trace metals.

[Time delay X (Nantucket Island, Mass.) and
time delay Y (Carolina Beach, N.C.) are Loran-C
time delay values for the 9960 Loran-C chain]

Field no.	Lab no.	Sta.	Yr	Mo	Dy	Water depth (m)	Latitude (degrees)	Longitude (degrees)	TDX (μ s)	TDY (μ s)
<u>Core profiles</u>										
C10111	W-228480	01	1984	3	31	2195	38.59846	-72.88164	26365.6	42588.7
C20131	W-228488	01	1984	8	3	2194	38.59893	-72.88046	26365.2	42589.0
C30111	W-229828	01	1984	12	2	2165	38.59750	-72.88283	26366.0	42588.1
C40121	W-232023	01	1985	5	17	2180	38.59798	-72.88223	26365.8	42588.4
C10611	W-228496	06	1984	5	3	2090	39.09238	-72.04884	26062.8	42877.7
C20611	W-228503	06	1984	3	1	2084	39.09313	-72.04866	26062.7	42878.1
C30631	W-229835	06	1984	11	28	2085	39.09371	-72.05032	26063.3	42878.4
C40611	W-231786	06	1985	5	15	2090	39.09278	-72.05080	26063.5	42877.9
C11311	W-228600	13	1984	4	2	1603	37.88783	-73.75032	26628.4	42121.0
C21311	W-228593	13	1984	8	7	1614	37.88799	-73.74901	26628.0	42121.2
C31311	W-229836	13	1984	11	30	1615	37.88770	-73.75066	26628.5	42120.9
C11411	W-230725	14	1984	4	2	1503	37.89526	-73.74525	26627.2	42125.9
C41421	W-231773	14	1985	5	19	1492	37.89685	-73.74211	26626.3	42127.1

Station blends - average position of three box core replicates

C10100	W-228518	01	1984	3	31	2177	38.59945	-72.88045	26365.2	42589.3
C10200	W-228519	02	1984	4	1	2021	38.59445	-72.89326	26369.6	42586.0
C10300	W-228520	03	1984	5	5	2057	38.61346	-72.85411	26356.2	42598.2
C10400	W-228521	04	1984	5	8	2108	38.73952	-72.68198	26296.7	42674.8
C10500	W-228522	05	1984	5	8	2067	38.84058	-72.55075	26249.9	42734.4
C10600	W-228523	06	1984	5	3	2089	39.09238	-72.04912	26062.9	42877.7
C10700	W-228524	07	1984	5	6	2107	38.45421	-73.05612	26423.0	42498.8
C10800	W-228525	08	1984	5	8	2149	38.45494	-73.08058	26431.4	42498.2
C10900	W-228526	09	1984	5	6	2106	38.28615	-73.24104	26480.7	42391.8
C11000	W-228527	10	1984	5	7	2095	37.86222	-73.33000	26496.3	42137.0
C11100	W-228528	11	1984	5	7	1518	38.66904	-72.93680	26386.4	42627.5
C11200	W-228529	12	1984	5	8	2501	38.48767	-72.70174	26302.3	42532.2
C11300	W-228627	13	1984	4	3	1613	37.88815	-73.75027	26628.4	42121.2
C11400	W-231657	14	1984	4	2	1500	37.89640	-73.74379	26626.8	42126.7
C20100	W-228530	01	1984	8	3	2194	38.60093	-72.88181	26365.7	42590.1
C20200	W-228531	02	1984	8	3	2014	38.59502	-72.89409	26369.9	42586.3
C20300	W-228532	03	1984	8	3	2055	38.61308	-72.85670	26357.1	42597.9
C20400	W-228533	04	1984	8	1	2114	38.74096	-72.68222	26296.8	42675.6
C20500	W-228534	05	1984	8	1	2084	38.83982	-72.54935	26249.4	42734.0
C20600	W-228535	06	1984	8	1	2077	39.09352	-72.04868	26062.7	42878.3
C20700	W-228536	07	1984	8	5	2102	38.45483	-73.05547	26422.8	42499.2
C20800	W-228537	08	1984	8	6	2159	38.45277	-73.07898	26430.8	42497.0

Appendix Table 1. - Navigation data for samples analyzed for trace metals -
Continued.

[Time delay X (Nantucket Island, Mass.) and
time delay Y (Carolina Beach, N.C.) are Loran-C
time delay values for the 9960 Loran-C chain]

Field no.	Lab no.	Sta.	Yr	Mo	Dy	Water depth (m)	Latitude (degrees)	Longitude (degrees)	TDX (μ s)	TDY (μ s)
<u>Station blends - average position of three box core replicates-Continued.</u>										
C20900	W-228538	09	1984	8	6	2112	38.28629	-73.24072	26480.6	42391.9
C21000	W-228539	10	1984	8	7	2100	37.86236	-73.32838	26495.8	42137.2
C21100	W-228540	11	1984	8	5	1509	38.66893	-72.93791	26386.8	42627.4
C21200	W-228541	12	1984	8	5	2509	38.48734	-72.69940	26301.5	42532.1
C21300	W-228542	13	1984	8	8	1617	37.88697	-73.75140	26628.7	42120.4
C30100	W-229811	01	1984	12	2	2175	38.59802	-72.88280	26366.0	42588.4
C30200	W-229812	02	1984	12	2	2013	38.59412	-72.89357	26369.7	42585.8
C30300	W-229813	03	1984	12	3	2050	38.61315	-72.85783	26357.5	43597.9
C30400	W-229814	04	1984	12	5	2107	38.73874	-72.68422	26297.5	42674.3
C30500	W-229815	05	1984	12	5	2082	38.83950	-72.55048	26249.8	42733.8
C30600	W-229816	06	1984	11	28	2088	39.09237	-72.04749	26062.3	42877.7
C30700	W-229817	07	1984	12	2	2110	38.45369	-73.05615	26423.0	42498.5
C30800	W-229818	08	1984	12	1	2153	38.45279	-73.07928	26430.9	42497.0
C30900	W-229819	09	1984	12	1	2107	38.28638	-73.23981	26480.3	42392.0
C31000	W-229820	10	1984	11	30	2100	37.86209	-73.33034	26496.4	42136.9
C31100	W-229821	11	1984	12	4	1527	38.66801	-72.93686	26386.4	42626.9
C31200	W-229822	12	1984	12	4	2507	38.48671	-72.70058	26301.9	42531.7
C31300	W-229823	13	1984	11	30	1614	37.88763	-73.75002	26628.3	42120.9
C40100	W-231781	01	1985	5	17	2192	38.59800	-72.88252	26365.9	42588.4
C40200	W-231782	02	1985	5	17	2011	38.59464	-72.89354	26369.7	42586.1
C40300	W-231783	03	1985	5	16	2051	38.61292	-72.85670	26357.1	42597.8
C40400	W-231784	04	1985	5	16	2097	38.73998	-72.68419	26297.5	42675.0
C40500	W-231785	05	1985	5	16	2078	38.84038	-72.54993	26249.6	42734.3
C40600	W-231786	06	1985	5	15	2087	39.09334	-72.05029	26063.3	42878.2
C40700	W-231787	07	1985	5	18	2102	38.28680	-73.24068	26480.6	42392.2
C40900	W-231788	09	1985	5	18	2102	38.28680	-73.24068	26480.6	42392.2
C41000	W-231789	10	1985	5	19	2095	37.86197	-73.32939	26496.1	42136.9
C41100	W-231790	11	1985	5	17	1510	38.66857	-72.93767	26386.7	42627.2
C41200	W-231791	12	1985	5	18	2505	38.48702	-72.69998	26301.7	42531.9
C41300	W-231792	13	1985	5	19	1609	37.88770	-73.75066	26628.5	42120.9
C41400	W-231793	14	1985	5	19	1491	37.89673	-73.74246	26626.4	42127.0

Appendix Table 1. - Navigation data for samples analyzed for trace metals -
Continued.

[Time delay X (Nantucket Island, Mass.) and
time delay Y (Carolina Beach, N.C.) are Loran-C
time delay values for the 9960 Loran-C chain]

Field no.	Lab no.	Sta.	Yr	Mo	Dy	Water depth (m)	Latitude (degrees)	Longitude (degrees)	TDX (μ s)	TDY (μ s)
<u>Replicate box core and within-box core comparisons</u>										
C10111	W-228607	01	1984	3	31	2195	38.59846	-72.88164	26365.6	42588.7
C10121	W-228608	01	1984	3	31	2195	38.59900	-72.88162	26365.6	42589.0
C10122	W-228609	01	1984	3	31	2195	38.59900	-72.88162	26365.6	42589.0
C10123	W-228610	01	1984	3	31	2195	38.59900	-72.88162	26365.6	42589.0
C10131	W-228611	01	1984	3	31	2143	38.60087	-72.87781	26364.3	42590.2
C10511	W-228612	05	1984	5	8	2055	38.84151	-72.55130	26250.1	42734.9
C10521	W-228613	05	1984	5	4	2065	38.84042	-72.55075	26249.9	42734.3
C10531	W-228614	05	1984	5	8	2080	38.83986	-72.55020	26249.7	42734.0
C11311	W-228624	13	1984	4	2	1613	37.88783	-73.75032	26628.4	42121.0
C11321	W-228625	13	1984	4	2	1613	37.88831	-73.75021	26628.4	42121.3
C11331	W-228626	13	1984	4	3	1613	37.88815	-73.75027	26628.4	42121.2
C20111	W-228513	01	1984	8	3	2209	38.60103	-72.88351	26366.3	42590.1
C20112	W-228514	01	1984	8	3	2209	38.60103	-72.88351	26366.3	42590.1
C20113	W-228515	01	1984	8	3	2209	38.60103	-72.88351	26366.3	42590.1
C20121	W-228516	01	1984	8	3	2179	38.60268	-72.88171	26365.7	42591.1
C20131	W-228517	01	1984	8	3	2194	38.59893	-72.88046	26365.2	42589.0
C20211	W-228615	02	1984	8	3	2019	38.59526	-72.89236	26369.3	42586.5
C20221	W-228616	02	1984	8	3	2014	38.59464	-72.89352	26369.7	42586.1
C20231	W-228617	02	1984	8	3	2004	38.59497	-72.89609	26370.6	42586.2
C20411	W-228618	04	1984	8	1	2124	38.74049	-72.68333	26297.2	42675.3
C20421	W-228619	04	1984	8	1	2114	38.74115	-72.68643	26298.3	42675.6
C20431	W-228620	04	1984	8	2	2099	38.74149	-72.68222	26296.8	42675.9
C20611	W-228621	06	1984	3	1	2084	39.09313	-72.04866	26062.7	42878.1
C20621	W-228622	06	1984	8	1	2084	39.09352	-72.04868	26062.7	42878.3
C20631	W-228623	06	1984	8	1	2084	39.09389	-72.04897	26062.8	42878.5
C21311	W-228510	13	1984	8	7	1614	37.88799	-73.74901	26628.0	42121.2
C21321	W-228511	13	1984	8	8	1619	37.88689	-73.75334	26629.3	42120.2
C21331	W-228512	13	1984	8	8	1619	37.88588	-73.75191	26628.8	42119.7

Appendix Table 1. - Navigation data for samples analyzed for trace metals -
Continued.

[Time delay X (Nantucket Island, Mass.) and
time delay Y (Carolina Beach, N.C.) are Loran-C
time delay values for the 9960 Loran-C chain]

Field no.	Lab no.	Sta.	Yr	Mo	Dy	Water depth (m)	Latitude (degrees)	Longitude (degrees)	TDX (μ s)	TDY (μ s)
Replicate box core and within box core comparisons-Continued										
C30111	W-229828	01	1984	12	2	2165	38.59750	-72.88283	26366.0	42588.1
C30112	W-229829	01	1984	12	2	2165	38.59750	-72.88283	26366.0	42588.1
C30113	W-229830	01	1984	12	2	2165	38.59750	-72.88283	26366.0	42588.1
C30121	W-229831	01	1984	12	2	2175	38.59804	-72.88309	26366.1	42588.4
C30131	W-229832	01	1984	12	3	2185	38.59854	-72.88278	26366.0	42588.7
C30611	W-229833	06	1984	11	28	2090	39.09178	-72.04581	26061.7	42877.4
C30621	W-229834	06	1984	11	28	2090	39.09160	-72.04633	26061.9	42877.3
C30631	W-229835	06	1984	11	28	2085	39.09371	-72.05032	26063.3	42878.4
C31311	W-229836	13	1984	11	30	1615	37.88770	-73.75066	26628.5	42120.9
C31321	W-229837	13	1984	11	30	1615	37.88819	-73.74928	26628.1	42121.3
C31331	W-229838	13	1984	11	30	1612	37.88689	-73.75078	26628.5	42120.4
C40111	W-231766	01	1985	5	17	2200	38.59804	-72.88309	26366.1	42588.4
C40121	W-231767	01	1985	5	17	2180	38.59798	-72.88223	26365.8	42588.4
C40131	W-231768	01	1985	5	17	2195	38.59816	-72.88223	26365.8	42588.5
C41311	W-231769	13	1985	5	19	1615	37.88750	-73.75037	26628.4	42120.8
C41321	W-231770	13	1985	5	19	1607	37.88794	-73.75125	26628.7	42121.0
C41331	W-231771	13	1985	5	19	1605	37.88754	-73.75067	26628.5	42120.8
C41411	W-231772	14	1985	5	19	1490	37.89661	-73.74280	26626.5	42126.9
C41412	W-231775	14	1985	5	19	1490	37.89661	-73.74280	26626.5	42126.9
C41413	W-231776	14	1985	5	19	1490	37.89661	-73.74280	26626.5	42126.9
C41421	W-231773	14	1985	5	19	1492	37.89685	-73.74211	26626.3	42127.1
C41431	W-231774	14	1985	5	19	1490	37.89669	-73.74214	26626.3	42127.0